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A PHOTOGRAPHIC DEVICE FOR THE COLLECTION OF ANTHROPOMETRIC DATA ON THE HAND

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A photographic device used to collect anthropometric data of the hand is described in this report. The hand photometric system, or photobox, was designed for measuring the human right hand, and evaluated for possible use in a large-scale Army anthropometric survey. The advantages of such a system are that it would be much faster than current methods of collecting hand data and would provide a permanent record from which measurements can be taken as needed.

Using the photobox, 16 hand measurements from 30 subjects were taken and compared to a more traditional method of collecting data. In this comparative method, finger breadths were measured by sliding calipers, while hand length, hand breadth, digit length, and crotch heights were measured from paper graphs on which landmark locations had been marked. This paper method was developed as a means of measuring hand records comparable to photobox silhouettes. Univariate statistics indicated that the results of the methods

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were very similar; differences between means of silhouette measurements and paper/caliper measurements ranged from 0.04 to 0.16 cm. Many of the larger differences were in finger breadths -- the caliper method consistently produced smaller results due to skin compression.

The repeatability of the methods was found to be very high. Though the photobox method produced consistently greater intertrial differences -- due to inexact hand alignment procedures and silhouette measuring techniques -- the differences were very small (0.2 mm to 0.3 mm). Several recommendations for improving repeatability are suggested.

The authors conclude that the photobox is an excellent alternative to other methods.

PREFACE

This report was prepared to fulfill requirements of contract DAAK60-86-C-0128 with the Material Systems Human Factors Branch, Science and Advanced Technology Directorate at the U.S. Army Natick Research, Development and Engineering Center (Natick). The Project Officer was Dr. Claire C. Gordon.

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INTRODUCTION

Dimensions of the hand have comprised only a very small proportion of the measurements obtained in previous large-scale anthropometric surveys of military personnel, although such dimensions are critical in the design of many kinds of vital military gear, from protective clothing to electronic control panels. For design purposes, the hand is essentially a collection of moving parts which must be considered individually and in combination. Since different data are often required for different design problems, a complete catalogue of hand data for known uses might include some 30 to 35 dimensions. Measuring this number of dimensions is a lengthy and costly undertaking in the context of an all-purpose body-size survey. For this reason, detailed hand data have usually been obtained in smaller special-purpose surveys of considerably fewer subjects.

The object of developing a photographic device which could reliably "record" hand dimensions for later measurement was to make it possible to collect a maximum amount of hand data on a large number of subjects in a minimum amount of time. A further benefit of hand photos is that they constitute a permanent record -- a resource to which designers or investigators can return for new measurements when they are needed for new applications.

This report describes the development and testing of a photographic system for gathering anthropometric data on the hand. This system is designed to capture the image of the right hand as a permanent record from which quick and accurate measurements of various lengths and breadths can be made as needed. A central feature of its design is the elimination of parallax, the problem of distortion or apparent change in size and shape of an object that has plagued photographic systems of the past. The hand photometric system is intended to record a shadowgram of the human right hand by the use of an optical arrangement designed to ensure that the shadow of the hand has the same dimensions as the parts of the hand casting the shadow.

Prior to initiating work on this task a review of the literature was undertaken to determine if any systems already in existence could be used (or adapted) to meet the stated goals. A few monophotometric devices have been developed and used in past anthropometric analyses. These systems have in common one of two approaches to the parallax problem: the use of equations to correct the measurements when enough information about the object's actual size and shape is available, or increasing the distance between the object and the camera to approximately 40 feet to minimize the effect of the viewing angle. Neither of these solutions was acceptable for our application. Thus, the development of a unique device was undertaken.

The first section of this report describes the optical problems encountered with photographic measuring devices of this type, and methods devised for their solution. The hand photometric system, or photobox, is fully described and illustrated. The second section describes an independent validation study of the accuracy and repeatability of hand measurements obtained through use of the system.

Finally, a user's guide is attached as Appendix A. This section provides all the information necessary for a user to operate and perform routine maintenance on the system.

DEVELOPMENT OF THE SYSTEM

To measure the maximum cross-sectional dimensions of the hand, one could use mechanical measuring devices such as calipers, or various optical scanning devices. The former are slow, tedious, and require considerable operator training to ensure uniform results. The latter methods require expensive equipment and skilled operators. An alternate approach was sought that would be less costly and require less operator training. Other objectives were that the resulting data be accurate to +/- 1 mm, inexpensive to record, and easy to evaluate, and that the apparatus be capable of photographing large numbers of subjects rapidly and with minimal maintenance.

The method chosen as best suited to meet the requirements of the task was based on shadowgraphy. An object such as a hand is illuminated by a beam of light. A shadow of the object is cast on a screen and the dimensions of the shadow can be measured, either on the original shadow or on some permanent record of the shadow. A photographic film lying in the shadow plane can record the shadow, or a camera can record an image of the shadow for later evaluation. In the latter case, a magnification factor would have to be applied to measurements of the image size, since the image is likely to be smaller than the object shadow to save film.

THE LIGHT SOURCE

Shown in Figure 1 is a point light source radiating light uniformly in all directions, and specifically illuminating an object and a screen beyond the object. The light source is assumed to be relatively close to the object. The rays of the light illuminate the screen except where the object blocks the rays, thus creating a shadow of the object on the screen. In this example, the shadow is considerably larger than the object due to the proximity of the light source and the diverging nature of the light rays.

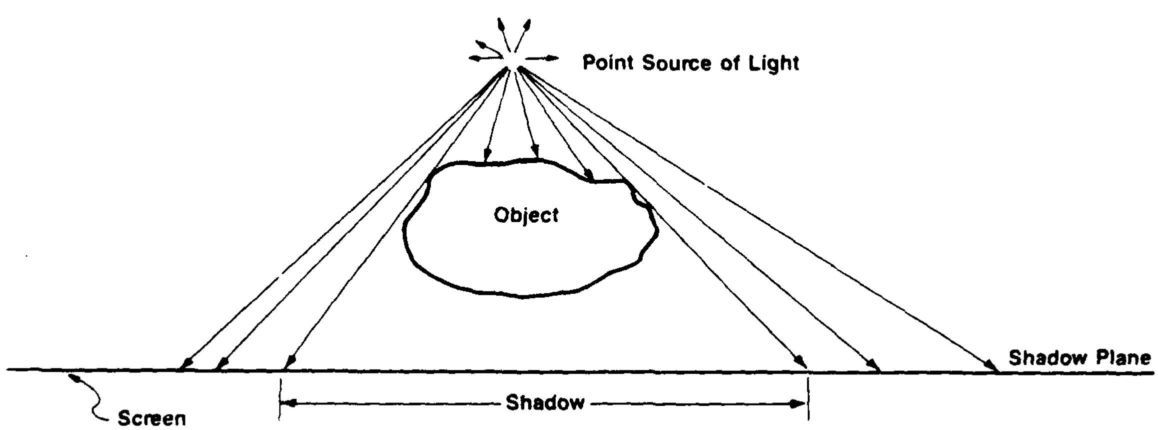

Figure 1. Shadows formed by close light sources.

The size of this discrepancy could be partially corrected by introducing a magnification factor which, when multiplied by the shadow dimensions, would

restore the true object dimensions. However, there are two problems with this simple approach. First, it can be seen in Figure 1 that the expanding light rays are not necessarily blocked by the parts of the object having the greatest lateral extent. This error is not corrected by use of a magnification factor. A second problem is that the parts of the object farther from the screen have different magnification factors than parts near the screen; this means that different magnification correction factors may be required for different parts of each object. These relationships are shown in Figure 2: the passenger and engine compartments of this car have the same width, but their shadows are of different widths. The two shadows have two different magnification factors:

$$M_h = W/S_h$$

$$M_H = W/S_H$$

For an arbitrary object such as this, these magnification factors cannot be calculated since the heights h, H are unknown.

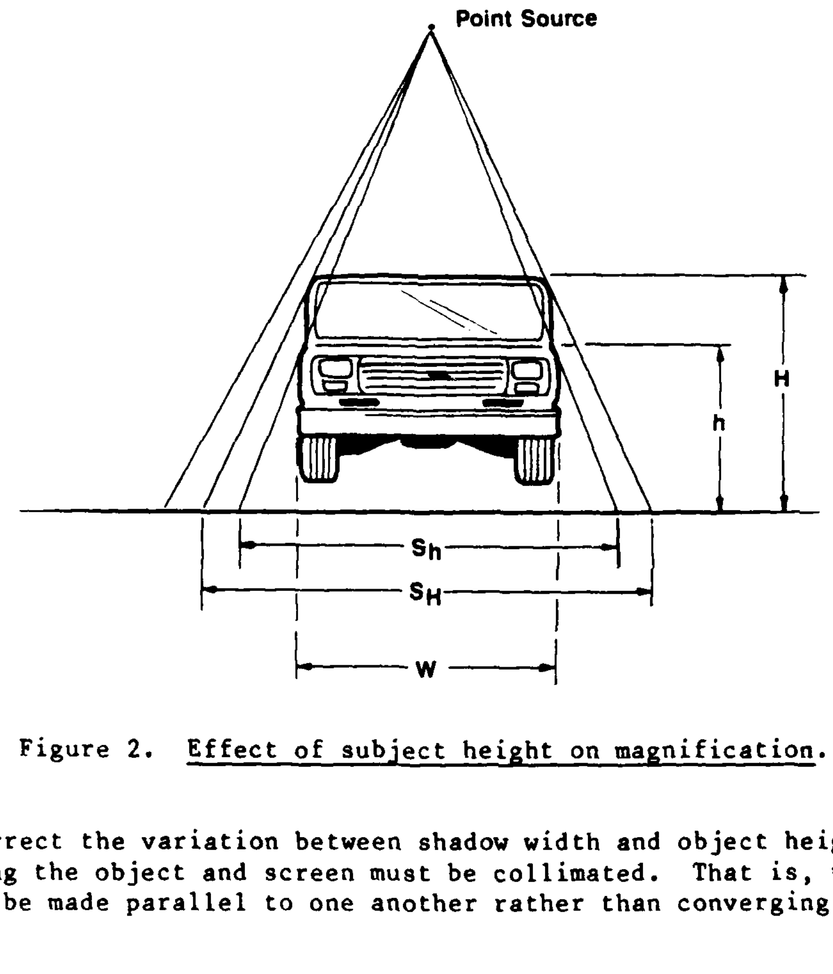

Figure 2. Effect of subject height on magnification.

To correct the variation between shadow width and object height, the light illuminating the object and screen must be collimated. That is, the rays of light must be made parallel to one another rather than converging or diverging.

This can be brought about in one of two ways. The light source can be moved to a great distance from the object so that only a very slightly diverging bundle of light rays actually strikes the object. This is shown in Figure 3. Starlight is a good example of light collimated by virtue of the distance of the source. This approach is very wasteful of light since only a small part of the light produced by the source is actually used. The immense physical size which would be required of such a device presents an additional problem.

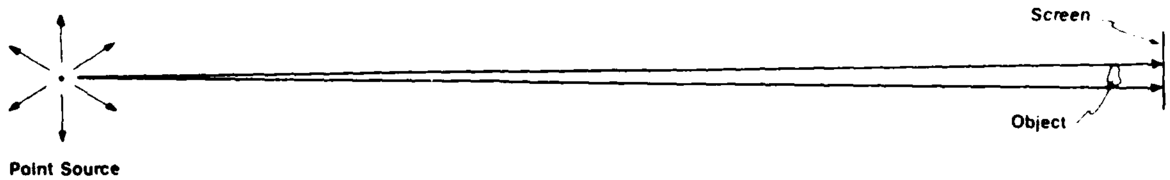

Figure 3. Effect of long source/object distance on magnification.

A second approach, more conservative of light, is to optically collimate the beam. This was the method chosen for use in the hand photometric device. Figure 4 shows the basic concept. The focal length of a lens is defined as the distance behind the lens to the point where the lens focuses a collimated beam of light (or very distant object) into a minimum spot. The process works in reverse, as well, so that a point source of light at the focal point of the lens will generate a collimated beam on the other side of the lens. For optimum collimation, the light source should be on the optical axis (usually the axis of rotational symmetry of the lens). Another important factor is source size. All real sources of light have some finite size. Only the point

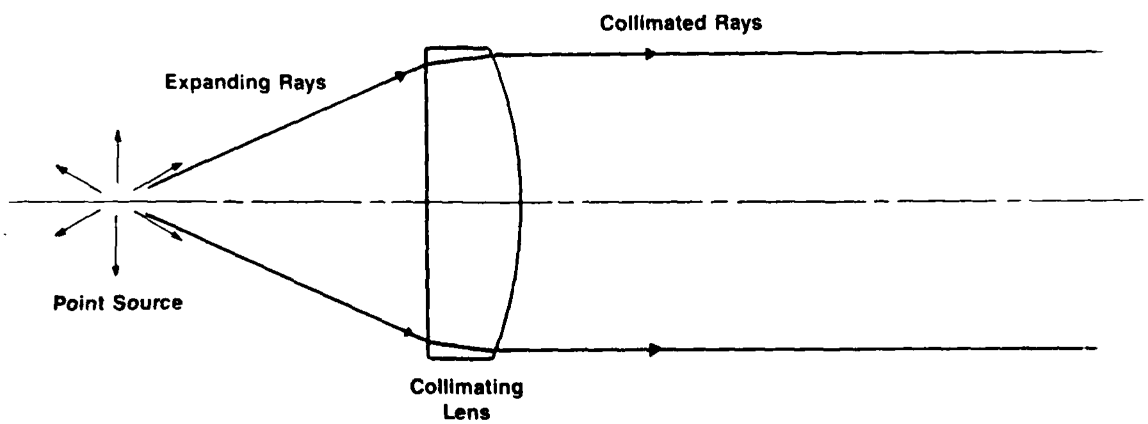

Figure 4. Collimation.

emitter at the focal point of the lens will generate a true collimated beam. Figure 5 shows this effect. Thus, for a given optical setup, the larger the source, the larger the errors in measurements of object size. For these purposes, where the maximum thickness of the hand above the screen could be about 50 mm, it can be demonstrated that the source size should not exceed about 2 mm if errors in hand size are to be less than 1 mm. Other sources of light, such as stray reflections or room lights must be reduced. For this reason, the system design incorporates various features intended to reduce interfering light sources.

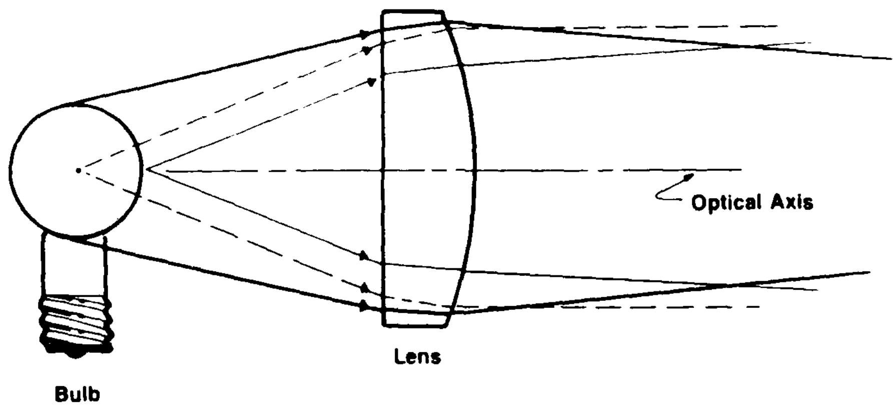

Figure 5. Effect of large light source on collimation.

Requirements for the light source are that it must be:

- inexpensive
- durable
- of adequate intensity to expose film
- easily replaced
- safe for operator and subject
- and that it must generate minimum heat.

The source chosen was an incandescent bulb operating on 5 volts DC and dissipating about four watts of electrical power. The manufacturer's rated lifetime is 30,000 hours.

THE CONDENSER

A light bulb consists of a glass envelope surrounding a hot filament. The size of the filament is often too large to meet the source size criteria for collimation, but the protective glass envelope prevents masking off the excess portions of the filament. One way around this dilemma is to re-image the light from the filament and then mask the image to the proper size. This is the approach used in the hand photometric system.

To reduce stray light and to control the size of the light source illuminating the collimator, an intermediate condenser and pinhole arrangement was designed. This consists of two f/0.7 aspheric (parabolic) lenses, 50 mm in diameter. The light source is one focal length to the left of the first lens, and the pinhole is one focal length to the right of the second lens. The distance between the lenses is not very important. Figure 6 illustrates these relationships. The condenser re-images the light source in space where the source size can be accessed and limited by installing a suitable pinhole at the focal plane of the second lens. The pinhole also serves to block most of the stray light coming from reflections or alternate sources. The fast aspheric lenses provide efficient light collection, and the dual lens design provides about four times as much light as comparable single-lens designs.

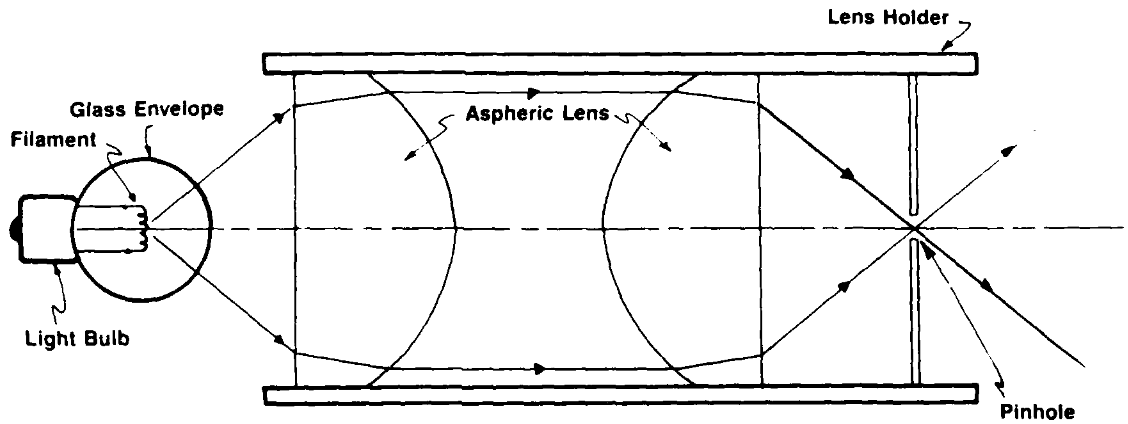

Figure 6. The condenser.

THE COLLIMATOR

The collimator consists of a single lens whose diameter is sufficient to create a collimated light beam large enough to cover the transverse dimensions of all objects that are to be measured. For present purposes, this diameter would be at least 250 mm. Such a lens would be very heavy and expensive if made of glass. To avoid this, a type of lens known as a Fresnel lens was specified. Fresnel lenses are normally molded in a plastic from high quality molds. This greatly reduces both cost and weight while preserving adequate performance in many applications. In principle, a Fresnel lens can be thought of as a "collapsed" lens where most of the internal lens material has been eliminated. This is possible since the major optical activity, light bending, occurs at the surfaces of the lens. A plano-convex Fresnel lens is illustrated in Figure 7, along with a superimposed outline of the lens it duplicates. Such aspheric lenses serve to reduce certain distortions common in ordinary lenses having spherical surfaces.

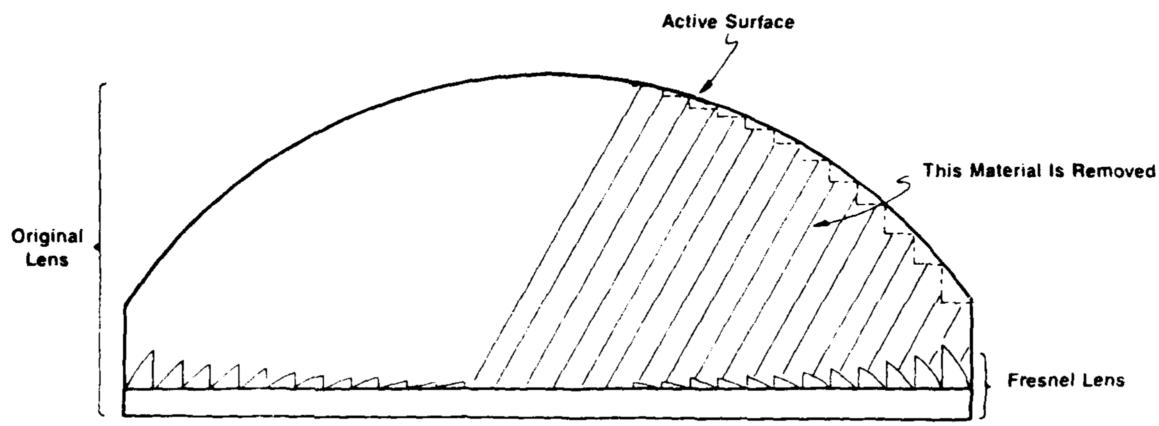

Figure 7. Principle of the Fresnel lens.

The collimating lens used in the photobox is a large-diameter molded plastic aspheric Fresnel lens. To generate a collimated beam, the Fresnel lens is located at a distance equal to its focal length from the condenser pinhole. For this application, all lenses must be centered on a common optical axis and oriented perpendicular to the axis to ensure a well-collimated beam. The arrangement is shown in Figure 8.

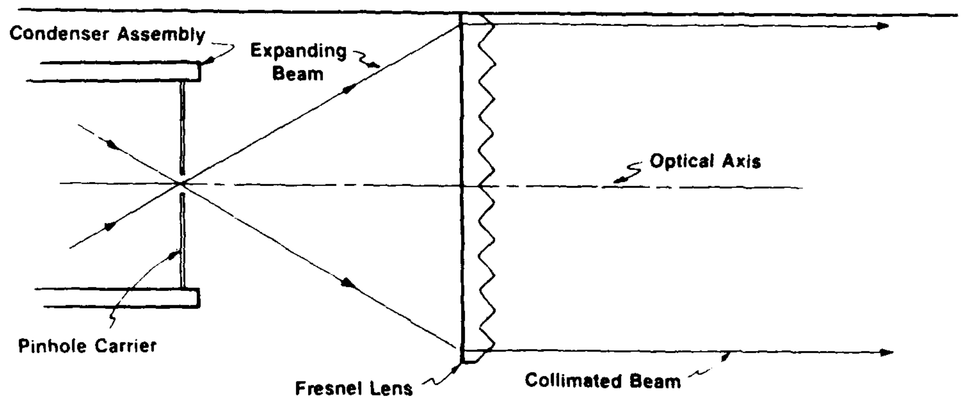

Figure 8. Fresnel lens collimation.

THE TRANSLUCENT DIFFUSING SCREEN

To adequately image the shadow/light outline of an object illuminated by a collimated beam, one cannot simply place a camera in the beam. The portion of the collimated beam not blocked by the object will be focused to a bright spot on the optical axis at the focal plane of the camera lens. This is the inverse of the process used to create the collimated beam in the first place. An image of the hand may or may not be formed depending on other factors, such as stray light. Even if such an image forms, it will be subject to the errors discussed in the section on the light source, namely changes in magnification with distance. Therefore, a screen must be inserted to perform

two functions: First, the screen forms a flat surface upon which the shadow of the object is cast by the collimated beam. The lack of height variation eliminates problems of variation in image magnification at the film plane. Second, the screen converts the collimated light into diffuse light, which is ideal for imaging purposes. Obviously, the screen must efficiently transmit the light with minimal absorption. Such a screen is called a translucent diffusing screen. Several such screens are available. These are, in order of increasing power to diffuse -- that is, to scatter light into increasingly large angles--ground glass, opal glass, and Marata screens. The ground glass gives the brightest image in the forward direction, though brightness falls off rapidly with off-axis viewing angles. The opal glass and Marata screen give uniformly illuminated but dimmer images. For the hand measuring system, the ground glass gave adequate results, with considerable savings of light. A ground glass diffuser screen is incorporated in the device.

THE CAMERA AND LENS

The camera is used to image the shadow of the hand cast onto the diffuser screen. This image is recorded on 35-mm film. Requirements for the camera were that it be reasonably automatic, but not autofocus, since the focus is constant. The camera used is the Nikon N2000 body with a 105-mm f/2.5 Nikkor lens. The lens was chosen to give full coverage of the diffuser screen at the required distance of about 1400 mm. This lens is also of good quality and provides flat focus to minimize added distortions in the shadowgrams. To reduce the vertical height of the device and make access to the camera more convenient, a folding mirror was installed just below the diffuser screen to reflect the view of the screen back up to the camera. The camera position is approximately in the plane of the diffuser screen and about 600 mm to the side. Figure 9 shows these relationships. The mirror is a large front-surface mirror designed to eliminate ghost images formed by glass front surfaces.

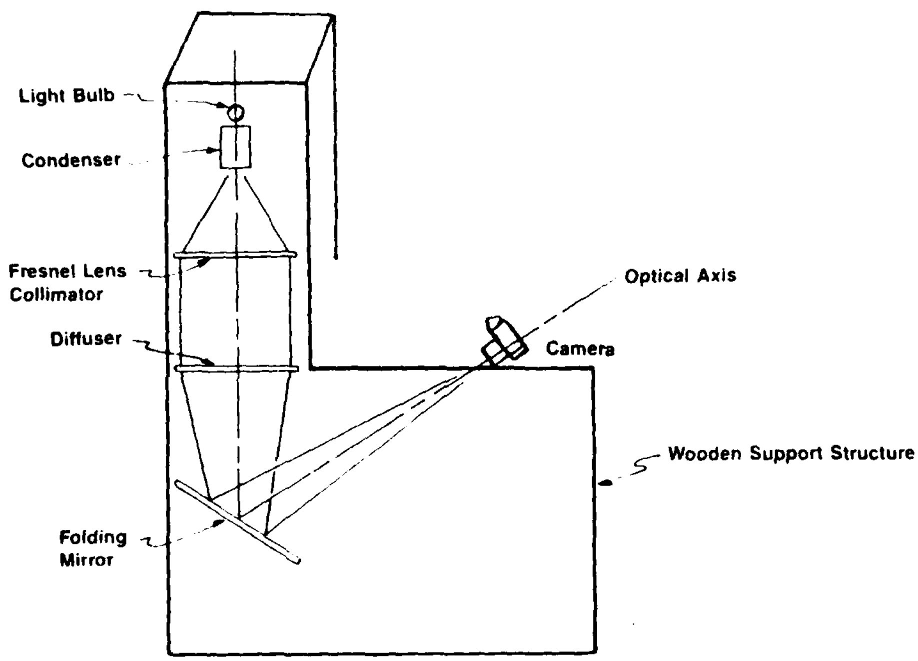

Figure 9. The photobox assembly.

Palm Pictures

A further requirement of the hand photometric system was that it provide not only silhouettes, but photographs of each hand showing such palm features as finger crotches, joint crease lines, and fingertip limits. This was accomplished by incorporating a slide mechanism to move the diffuser plate out of the field of view and by illuminating the palm with an electronic flash unit synchronized with the camera shutter. A magnetic proximity switch senses when the diffuser plate is pulled out of the way and turns on a relay that connects the flash controller to the camera. A second relay turns off the flash unit when the AC power is off, so internal battery power is not drained. The angle of illumination was chosen to highlight palm details, particularly creases, which can be used as measurement landmarks.

Hand Alignment

In order to ensure that different hand shadowgrams represent similar hand positions and finger spreads, a hand-positioning pattern is placed in a sliding tray above the hand and is illuminated by the collimated beam, thus projecting the pattern onto the subject's hand. Once the hand is positioned, the pattern is retracted by a slide mechanism so as not to obscure hand features. The pattern and diffuser plate slides are manually positioned in a predetermined sequence by the operator, and are sealed to prevent excessive light and dust from entering the interior of the photobox.

Stray Light

The interior of the photobox is painted flat black to reduce stray scattered light. A black velvet sleeve surrounds the camera lens and prevents stray light and dust from entering. In strong room light, a movable screen, such as a flap of black velvet fabric, must be provided to prevent room light from entering the interior of the system through the hand window, while at the same time allowing for visual inspection during hand alignment procedures.

Camera Release

The Nikon N2000 camera automatically advances newly loaded film to the first exposure, and again each time the shutter is pressed. Film must be manually rewound. Thus, once the hand is aligned and the slide levers are positioned, it is only necessary to press the shutter release and the camera will expose and advance the film for the next exposure. The camera has a multiple exposure mode that should not be used, as it produces several identical pictures. A remote shutter release cable is provided.

A picture of the photobox is shown in Figure 10. Instructions for operating and cleaning the device are given in Appendix A.

Figure 10. Hand Photometric System.

VALIDATION

METHOD

The ability of the hand photometric system to provide accurate information was analyzed in a series of trials. Because of the variability inherent in positioning and measuring the soft tissues of the hand, metal objects such as coins and calibration rods were used as test objects in the first group of tests. A number of pictures were taken of several kinds of such objects to determine the accuracy and repeatability of the measurements, and to compare results obtained by different measurers. Because the time involved in developing prints of all the negatives would have been prohibitive, the negatives were projected through a photographic enlarger or an overhead projector onto a white background, and measurements were taken from the images with Vernier calipers.

Two things were of particular concern in this initial stage of the testing. The first was the effect of the height of an object, since the closer the object comes to the lens, the more exaggerated are the detrimental effects of poorly collimated light on measurement accuracy. The second point of interest was the effect of the location of the object on the viewing screen, that is, its placement at the center or near the perimeters of the photographic field.

These questions were addressed by repeated measurements of a metal calibration rod shaped in a series of stairsteps ranging in width from 5 mm to 35 mm (Figure 11). The rod was first placed on various objects ranging in height from 2.3 cm to 10.9 cm and photographed in these positions. The rod was then placed directly on the viewing screen and photographed in many different locations to test for any distortion caused by the structure of the Fresnel lens.

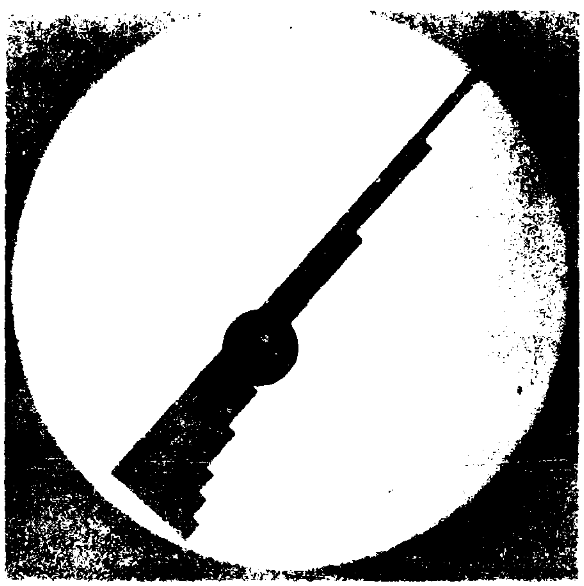

Figure 11. Calibration rod (elevated on a round object).

Results indicated that the photobox is reliable as well as accurate, with errors and retest differences ranging from 0.1 mm to 0.6 mm. These small differences might have been reduced even further had it been discovered earlier in the measurement procedure that the negatives did not lie completely flat in the enlarger tray, thus raising the possibility of distortion in the images projected by the enlarger. This potential source of trouble was later eliminated by placing a flat piece of glass on top of the negatives and using an overhead projector.

With confirmation that the system was accurately recording inanimate objects, measurement of human subjects was begun. In this phase of the study, reliability and repeatability were checked by having each of two investigators photograph and measure each subject twice. Silhouette measurements of 17 female and 13 male subjects, obtained via the photobox, were compared to data obtained by a more traditional means of measuring permanent hand records.

Hand records were collected in the following way on each subject:

A point on the subject's wrist known as the stylion landmark was located and marked by one investigator. This landmark is the most distal point of the radius (the bone on the thumb side of the lower arm).

For the photographs, the subject's hand was placed in the photobox and positioned with the aid of an indicator rod placed on the stylion landmark and a projected grid pattern for placement of the fingers. A narrow tray containing the subject's assigned number was placed next to the hand for identification purposes. The alignment grid and resulting silhouette are shown in Figures 12 and 13.

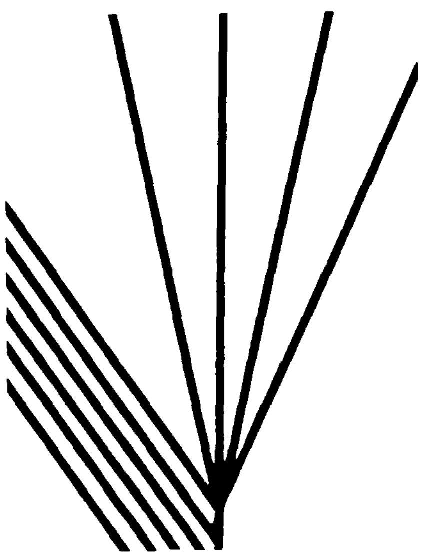

Figure 12. Alignment grid (actual size 8 1/2" x 11").

Figure 13. Sample silhouette.

Among the traditional methods for measuring the straightened flat hand is use of a measuring board for obtaining most length and width dimensions. The hand is placed on a paper pattern used to standardize its position, and selected points such as fingertips are marked for later measurement. This method was used in this validation study since it would most closely approximate the manner in which dimensions were obtained from photographic images.

A technique similar to that used by Garrett (1970)[1] was employed. Subjects placed their right hands on a paper copy of the hand alignment grid projected in the photobox (see Figure 12). Investigators made small marks on the paper at the stylion landmark, at the tops of all the fingertips, at the crotches between the fingers, and at the widest point on the metacarpo-phalangeal joints outside of the forefinger (digit 2) and the little finger (digit 5). Digit breadths were measured directly on the fingers with sliding calipers for several reasons, chiefly because the rotation of the fingers as they lay on the paper prevented investigators from obtaining accurate breadths by means of marking. This was true in virtually all cases of subjects' thumbs, in many cases of their little fingers, and in some cases of other fingers.

A total of 16 measurements were taken by both methods: hand breadth, hand length, five digit breadths, five digit lengths, and four crotch heights. Silhouettes, as noted, were projected on a wall, and the known length of the subject number tray was used to determine the scale of the projected images. For both sets of measurements, a reference line, perpendicular to the long axis of the hand, was drawn through the stylion landmark to create a baseline from which to measure crotch heights and hand length. Digit lengths were measured as the distances between crotch points and the tips of the digits. (Digit 1 was measured to the crotch between thumb and forefinger, digits 2 and 3 to the crotch between them, digit 4 to the crotch between digits 3 and 4, and digit 5 to the crotch between digits 4 and 5.)

A clear ruler was used to measure all the dimensions from the paper records, and to measure hand length from the silhouettes. All other silhouette dimensions were measured with Vernier calipers.

RESULTS

Comparisons of measurements obtained on both sets of hand records are summarized in Table 1. (The actual comparative data are presented in stem leaf graphs in Appendix B.) Measurement values in each case represent the means of 120 measurements (30 subjects x 2 investigators x 2 trials).

As can be seen in Table 1, the differences between the means for the two methods are, in most cases, very small. The somewhat larger differences in the finger breadth measurements reflect the use of the calipers directly on the fingers, and were expected since the pressure exerted by the instrument, however light, results in a slight compression of the flesh.

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[1]Garrett, John W. 1970. <u>Anthropometry of the Hands of Male Air Force Flight Personnel</u>. AMRL-TR-69-42. Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

TABLE 1. Comparison of Measurements of the Hand (measurements are in centimeters).

	PAPER/CALIPER Mean	PAPER/CALIPER SD	SILHOUETTE Mean	SILHOUETTE SD	Difference Between Means
Hand Breadth	8.81	0.76	8.92	0.73	0.11
Digit 1 Breadth	2.12	0.23	2.25	0.23	0.13
Digit 2 Breadth	2.02	0.20	2.17	0.21	0.15
Digit 3 Breadth	2.00	0.21	2.15	0.21	0.15
Digit 4 Breadth	1.86	0.20	2.00	0.21	0.14
Digit 5 Breadth	1.62	0.19	1.73	0.18	0.11
Hand Length	18.97	1.63	18.93	1.55	0.04
Digit 1 Length	5.80	0.51	5.73	0.49	0.07
Digit 2 Length	7.47	0.53	7.51	0.52	0.04
Digit 3 Length	8.19	0.67	8.26	0.65	0.07
Digit 4 Length	7.30	0.66	7.37	0.65	0.07
Digit 5 Length	5.75	0.59	5.82	0.58	0.07
Crotch 1 Height	6.72	0.81	6.83	0.81	0.11
Crotch 2 Height	10.83	1.04	10.84	1.00	0.01
Crotch 3 Height	10.78	1.05	10.71	1.01	0.07
Crotch 4 Height	9.52	1.01	9.36	1.00	0.16

The repeatability of measuring subjects, using the silhouette method, was initially examined by looking at the frequency distribution of the differences between the trials (Appendix C, Tables C-1 to C-16). This testing reflects not only the measurers' ability to realign each subject's hand exactly, but also their ability to measure the photographic image with calipers. Combining all measurements, there were 960 intertrial differences. Of these, 72.4 percent were one millimeter or less, 17.1 percent were greater than one millimeter but less than or equal to two millimeters, and 10.5 percent were greater than two millimeters. These frequencies are broken down by measurement type in Table 2. A closer look showed 44 (4.6 percent) differences greater than three millimeters. Of these, one was a hand breadth measurement, three were digit 1 lengths, six were hand lengths, and 34 were crotch heights.

TABLE 2. Intertrial Differences of Silhoutte Measurements.

	$\leq$1mm	>1mm, $\leq$2mm	>2mm
Hand and Digit Breadths	86.9%	11.7%	1.4%
Digit Lengths	78.7%	19.0%	2.3%
Crotch Heights and Hand Length	48.7%	21.7%	29.7%

With the exception of the crotches and hand length, the repeatability of the silhouette measures showed very good results. The great majority of the differences between trials were within 1 mm. However, the hand length and crotch height values needed further investigation. Ten silhouettes which exhibited differences of 5 mm or more in these measurements were reexamined in an effort to find the source of the errors.

The method used to examine the differences was to project the first silhouette onto a reference grid and mark the stylion indicator rod, the crotches and fingertips. The second silhouette (retest) was superimposed over the reference grid with the marks and landmarks aligned to see if the points lined up, or if they had changed.

An example of this method is shown in Figure 14. In the figure, the dotted line represents the outline of the first trial of one silhouette. The solid lines indicate the overlaid digit tips, crotch points, and stylion rod of the second trial. As can be seen when the tips of digits 2, 3, 4, and 5 and crotches 2, 3, and 4 are aligned, the tip of digit 1, crotch 1, and the stylion rod are offset.

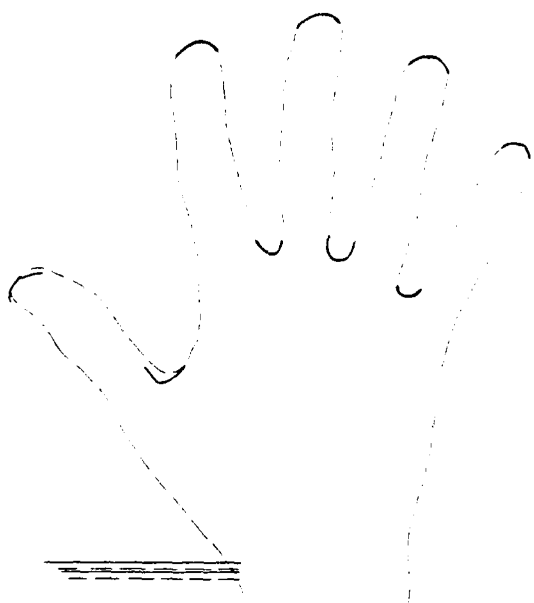

Figure 14. Comparison of silhouette trials.

In 8 of the 10 cases the stylion indicator rod did not line up on the two silhouettes. This means that when the investigators repositioned a subject's hand for the second photograph, the rod was not aligned with the same point on the wrist (the landmark was not remarked between trials). Since this point was the baseline for all the crotches and hand length, it explains a great deal of the difference observed. While this alignment problem does not make the measurements identical, it brings eight of ten back into the 1- to 3-mm difference range. In the user's manual (Appendix A), a more exact description

of how to position the hand relative to the indicator rod has been defined. There are two additional explanations for the crotch height differences. For crotch 1 height the alignment of the thumb has a great effect on the shape of the soft tissues in the crotch area (Figure 14). This is the most difficult part of the hand to align. For crotch 4 height the problem may also be in the reference line through the stylion. If this line is not exactly perpendicular to digit 3 (imagine the lines diverging slightly), the differences would be exaggerated at crotch 4.

Each of these problems will be explored further.

Multivariate Analysis

The data from these measurements and the intertrial differences were subjected to a number of multivariate statistical procedures. Of interest in the analysis was whether the investigators' results were significantly different from one another (investigator effects), whether the paper/caliper and silhouette methods were significantly different from one another (method effect) or whether the differences between methods were inconsistent across investigators (investigator/method interaction).

The results of the statistical analyses of the measurements and intertrial differences are presented in Appendix D. When an interaction was found, the investigator and method effects were invalid so only the interaction results are given. To further clarify the interactions, the analysis was repeated with investigators separated, and trivariate plots were made.

Multiple analysis of variance (MANOVA) was used as the statistical tool. For analytical convenience the variables to be included in the MANOVAS were divided into three sets, by type of measurement, and analyzed as groups. The sixteen variables were divided as follows:

Set 1	Set 2	Set 3
Hand Breadth	Hand Length	Crotch 1 Height
Digit 1 Breadth	Digit 1 Length	Crotch 2 Height
Digit 2 Breadth	Digit 2 Length	Crotch 3 Height
Digit 3 Breadth	Digit 3 Length	Crotch 4 Height
Digit 4 Breadth	Digit 4 Length	
Digit 5 Breadth	Digit 5 Length	

Some noteworthy findings are briefly summarized below:

Hand and Digit Breadths (See Appendix D, Tables D-1 to D-3 and Figure D-1.)

For the actual measurements, a significant investigator/method interaction effect was found. With continued analysis, it was discovered that, though both investigators were consistent in producing larger silhouette measurements than caliper measurements (as noted above), their degree of difference was not the same.

Intertrial differences of the hand and digit breadths revealed a significant effect for method only. This indicates that the degree of difference between the first and second trial varied by the method. Greater differences were found in the silhouette method and may have been due to the lack of obvious landmarks (the center of the knuckle is not so easily apparent on a silhouette).

Hand and Digit Lengths (See Appendix D, Tables D-4 and D-5.)

The lack of significant results for investigator effects indicates that the investigators tended to produce essentially the same measures. The significant method effect, however, indicates that the measurements were not the same for paper and silhouette. Further analysis indicated that the difference in methods appears to be the consequence of a difference in the recording of digit 1 versus digits 3 and 5. Two sources of variability could account for this: (1) digit 1 was more difficult to mark in the paper method because the distance of the thumb crotch from the paper and the consistency of the tissues at that location made it hard to transfer to the paper, and (2) the orientation of the thumb was the most difficult alignment problem.

The results on the intertrial differences for hand and digit lengths indicated a lack of significant investigator effect, demonstrating that each investigator's degree of differences between trials was essentially the same as the other's. The lack of method effect indicates that these differences did not vary between methods, i.e., both methods appear to be equally repeatable. There was no interaction effect.

Crotch Heights (See Appendix D, Tables D-6 to D-8 and Figure D-2.)

Analysis of the four crotch height measurements indicates no significant investigator effect, i.e., the two investigators produced essentially the same measurements. There was a significant method effect which appears to be a contrast between crotch 2 and 4. Since the orientation of the hand can affect these measures, it is likely that this is an indicator of an orientation or alignment difference. In other words, the base line through the stylion landmark may have been drawn in a consistently different place for one method than for the other. No interaction effect between investigator and method was found.

Results for intertrial differences of crotch heights indicate an interaction of investigators and methods. Further analysis showed that the first investigator had lower intertrial differences than the second investigator on the paper method, but that for the silhouettes the second investigator had lower intertrial differences. It should also be noted that, for crotches 1, 2, and 3, the intertrial differences for both investigators were lower for the paper method than the silhouette method. As with previous results, this could be indicative of an inconsistency in hand orientation.

In summary, hand and digit length measurements were the most repeatable across measurers and methods. The small inconsistencies found across methods appeared to be due to misalignment of the thumb. Larger breadth measurements obtained on the silhouettes were obviously due to the lack of compression on

soft tissue which occurred on the caliper measurements. Difficulty in repeating the silhouette method is possibly due to lack of visual landmarks. In measuring crotch heights, the differences between methods and trials can be explained in large part by imprecision in orienting the hand.

In short, many of the differences found between silhouette and other methods, though small, could be eliminated by improving the hand alignment procedures. It should also be noted that a more exact method of extracting data from the photographic images should be examined. Distortion of the overhead projection and the difficulty of taking measurements from a vertical plane (images were projected on a wall) are thought to have contributed to many of the intertrial differences found for the silhouette method.

CONCLUSIONS AND RECOMMENDATIONS

Overall, the data analysis suggests that the repeatability of both methods was very high. Though intertrial differences for the silhouette method were consistently greater, these differences were very small -- on the order of 0.2 mm to 0.3 mm, on the average. It appears that the repeatability of the silhouette method could easily be improved.

While caliper measurements of hand length and breadth have been satisfactory for the limited purposes to which they are put, some other measurements of the hand do not lend themselves as well to this traditional technique. For example, tissue deformation and standardization of finger positions present problems when using instruments to directly measure crotch heights.

The paper method has several important advantages over caliper measurements. It is sparing of subject time, allows for standardization of finger positions, and provides a permanent record which allows for remeasurement of doubtful points. The hand photometric system described in this report enhances these advantages even further. It is faster than the paper method -- thus, more suitable for large surveys -- and provides permanent hand records (silhouette and palm print) from which a variety of unforeseen measurements can be made from new landmarks.

Given the fine results of the measurements on the rigid objects and the reasonable retests on live subjects, the photographic system appears to be an excellent alternative to traditional methods of measuring the hand.

APPENDIX A

INSTRUCTION MANUAL FOR THE OPERATION AND MAINTENANCE OF THE HAND PHOTOMETRIC SYSTEM

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Step-by-step instructions for the operation and care of the hand photometric system follow. Several steps need to be performed only after shipping and are so indicated; others are followed routinely.

OPERATION

1. The hand photometric system requires a grounded (three-pronged) electric outlet. Plug in the 19-foot long electrical cord attached to the back panel (Figure A-1, A) into a normal 1100 AC outlet.

2. Flip the power switch up to turn on the device (Figure A-1, B). The light to the left of the switch will indicate that the power is on.

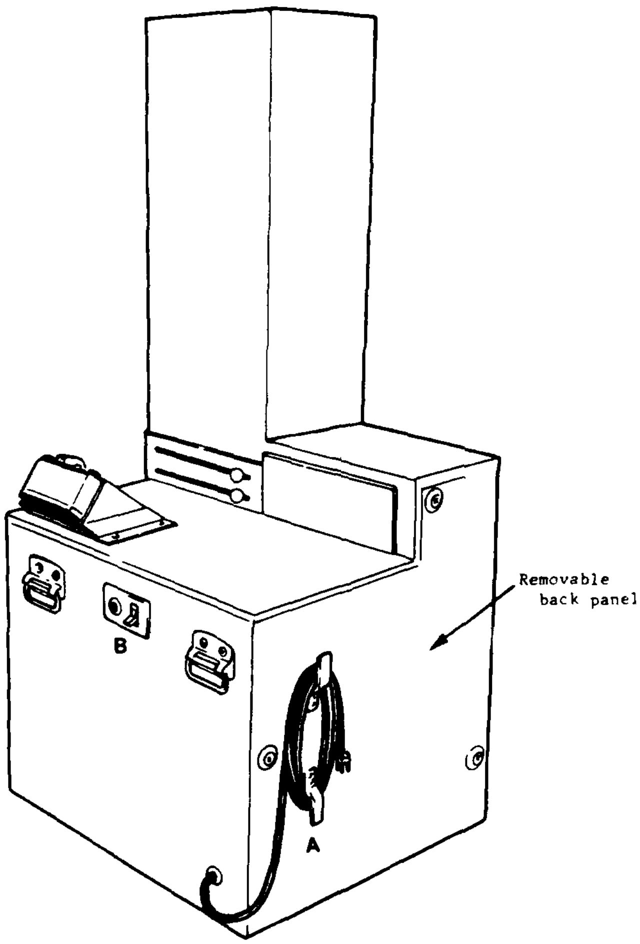

Figure A-1. Hand Photometric System: rear left view.

3. The photobox in which the subjects place their hands is accessed by a swing-down door that becomes the arm rest in its open position (see Figure A-2). The door is held in a closed position by a tension catch. To open the area, release the catch by pulling the knob out and up, simultaneously (see Figure A-3). Some sticking may occur, so pull the arm rest down slowly.

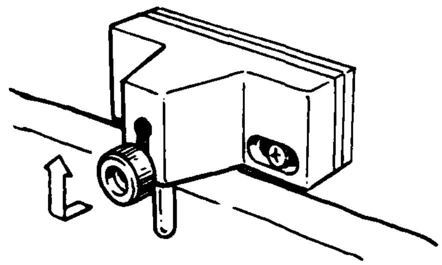

Figure A-3. Arm rest shelf catch.

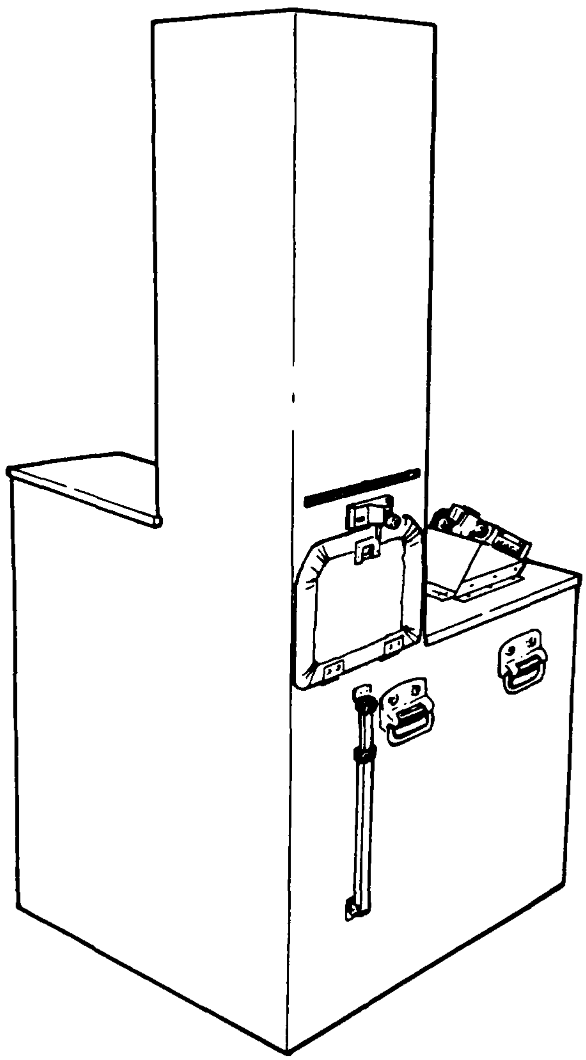

Figure A-2. Hand Photometric System: right front view.

4. Adjust the arm rest so that it is parallel to the floor by raising or lowering the extension bar (Figure A-4). The end of the extension bar should be secured firmly in a notch underneath the arm rest.

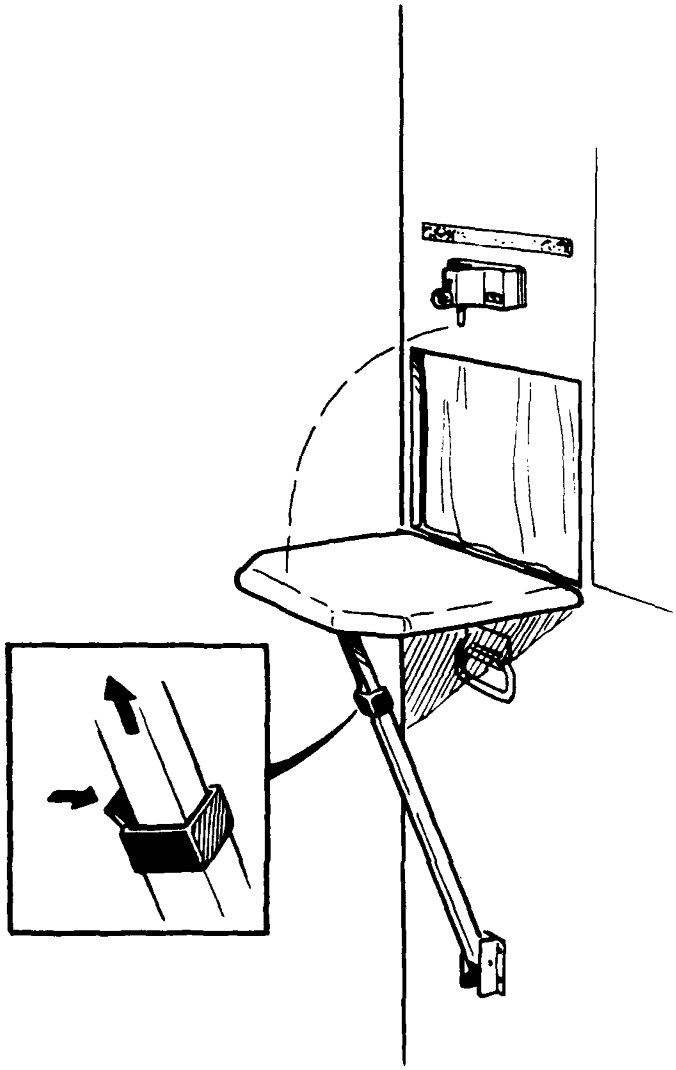

Figure A-4. Arm rest shelf and extension bar.

5. Raise the black curtain and secure it to the velcro strip (Figure A-5, A).

6. The subject is seated to the left side of the device so that the right elbow rests comfortably on the arm rest (Figure A-5). The subject should remove all jewelry from the right hand and arm.

7. On the right side of the tall section of the box are two round knobs. The upper knob (Figure A-5, B) slides the alignment grid forward and back, and the lower knob (Figure A-5, C) slides the diffuser plate forward and back. After the subject is seated, pull the alignment grid forward so that the grid is projected onto the subject's hand.

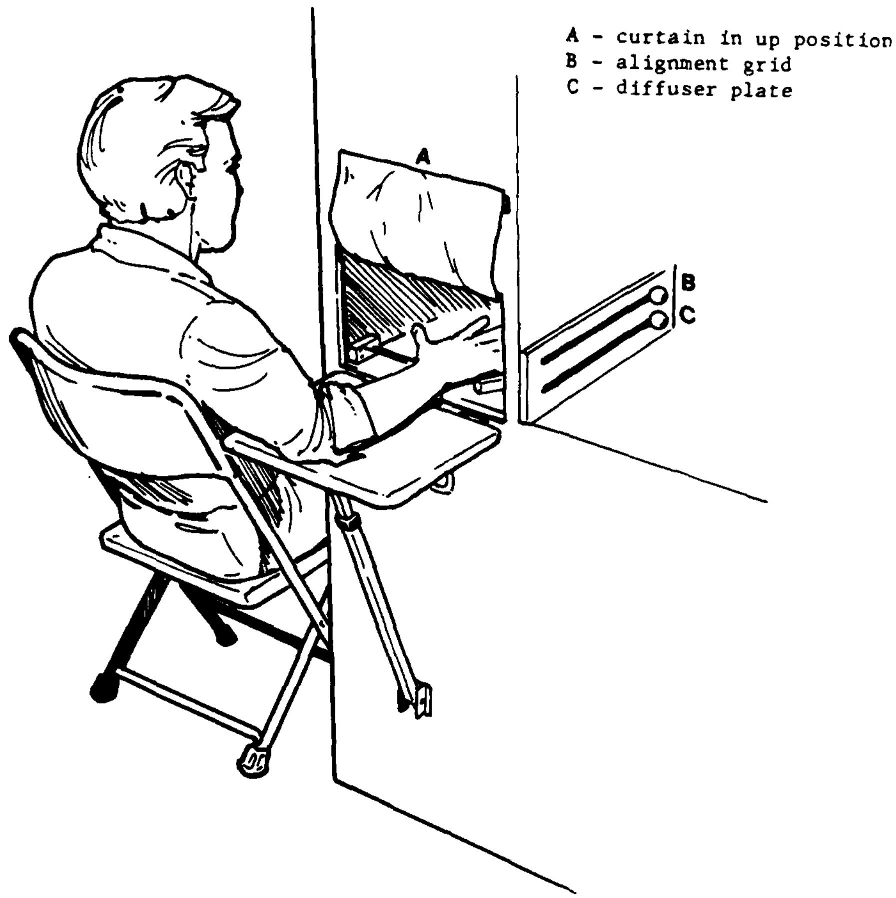

Figure A-5. Subject seated at photobox.

8. Carefully align the subject's hand (Figure A-6) using the grid and the stylion indicator rod (Figure A-7). This is a six-part process:

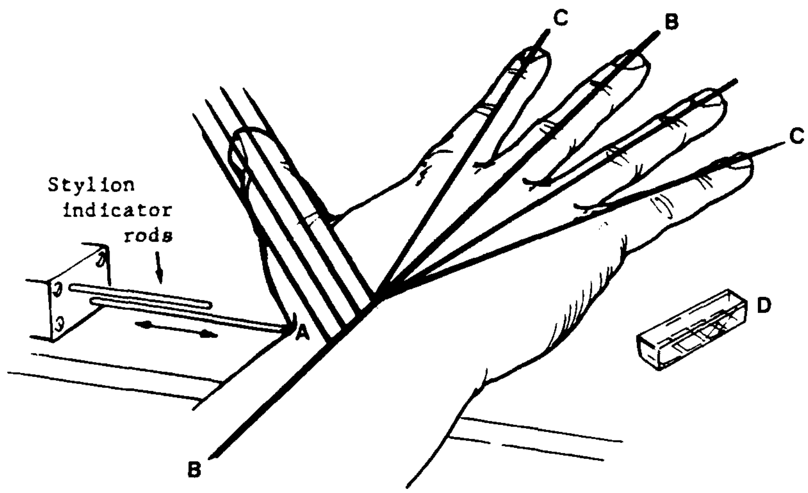

Figure A-6. Hand alignment grid.

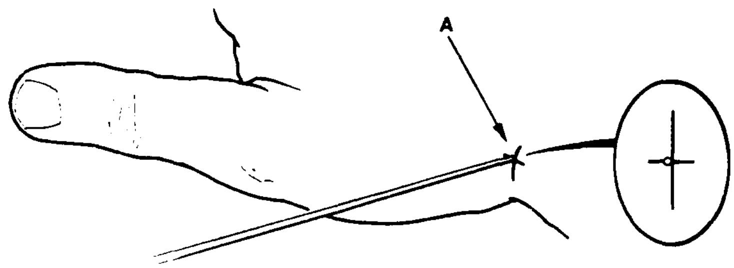

Figure A-7. Stylion indicator rod alignment.

(a) Place the subject's hand in the center of the glass plate, moving the subject's hand forward and backward until the front side of the indicator rod is in contact with the stylion mark as illustrated in Figure A-7. There are two stylion indicator rods, one closer to the inside of the box for smaller hands and one closer to the outside for larger hands.

(b) Keeping the stylion landmark aligned with the rod, rotate the hand side to side until the second-from-left long grid line (line B in Figure A-6) is projected directly over the third metacarpo-phalangeal joint and runs down the long axis of the forearm through the center of the wrist. That grid line B does not appear to be aligned with the center of the wrist in Figure A-6 is a function of the perspective from which the hand is drawn.

This illustrates the importance of looking straight down on the wrist while orienting it on the grid. If the hand is viewed from an angle, it will be incorrectly placed.

(c) Instruct the subject to place the hand firmly enough on the plate so that all the fleshy pads are touching. No extra pressure should be exerted. Adjust the alignment grid by using the upper knob to slide the plate back and forth on the track until the two long outside lines (Figure A-5, C) are projected over the second and fifth metacarpophalangeal joints. With three fingers lined up, the fourth metacarpophalangeal joint should automatically be aligned. Not all subjects have perfectly straight hands and fingers. In such cases line them up through the third finger and average out the discrepancies between the second and fifth fingers.

(d) Adjust the fingers so that the grid lines pass over the center of each fingertip.

(e) The thumb is aligned so that its long axis is parallel to the grid lines. Because the thumb joint allows for a great deal of freedom of movement, the thumb can be parallel in several positions. Place the thumb so it is parallel with the first set of lines closest to the hand. That is, begin with the thumb placed next to the hand, slowly abduct it (move it away from the hand), and stop when it is parallel with the grid.

(f) When the hand is aligned, check to be sure that the stylion indicator rod is still in contact with the stylion landmark. Instruct the subject to hold the hand still. Now, push back the upper knob (Figure A-5, B), removing the grid.

9. Place the subject number tray next to, but not touching, the right side of the hand (Figure A-6, D)

10. Lower the black curtain to shield out light.

11. Look through the camera lens to ensure that

    - the grid is completely out of the way,
    - the subject numbers are legible,
    - the diffuser plate is properly placed (see step 12),
    - the stylion indicator is in direct contact with the skin.

12. Two pictures will be taken of each subject: (a) a silhouette in which the diffuser plate is moved forward toward the subject, using the lower round knob (Figure A-5, C); and, (b) a palm picture which requires that the diffuser plate be removed by pushing the lower round knob toward the back of the device. A flash required for this picture is wired by way of a relay switch to the diffuser plate track. That is, it will flash automatically if the diffuser plate is properly removed.

13. After both pictures are taken, lift the curtain, pull the stylion indicator rod away from the hand, and ask the subject to remove the hand.

14. If there will be more than a 10-minute interval between subjects, turn the device off.

15. As needed (usually after use by eight or ten subjects), clean the glass plate on which subjects rest their hands by spraying glass cleaner on a lint-free cloth and then wiping the plate. DO NOT SPRAY ANYTHING INSIDE THE DEVICE. If necessary, the diffuser plate and alignment grid may be cleaned the same way.

CAMERA SETTING AND OPERATIONS

The hand photometric system uses a Nikon N2000 35-mm camera (Figure A-8), and 24- or 36-exposure 400 ASA black and white film. The camera is rigidly mounted in the photobox by means of a wing-nut screw inserted through the box frame into the camera. It should be removed only if the front settings are disturbed or if it gets out of focus. The lens is protected by a black velvet sleeve to shield out light and dust.

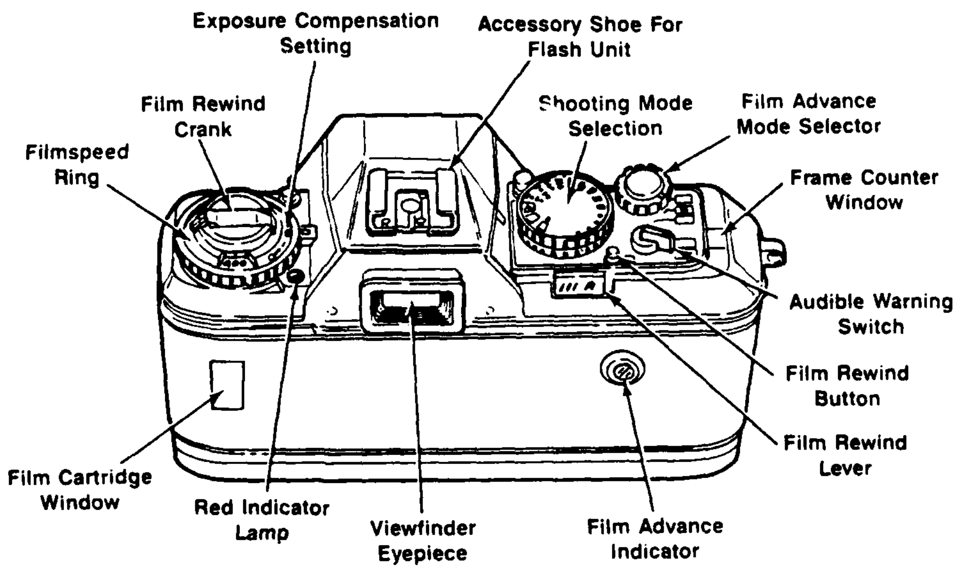

Figure A-8. Nikon N2000 35-mm camera.

After shipping, or in the event of its being jarred, the following settings should be checked:

1. Check focus by placing the subject number tray on the viewing plate to see if the numbers are clearly visible. Because the camera is firmly mounted and the focusing apparatus has been sealed by tape into the correct position, it should not require adjustment. If, however, it does become unfocused, reset to proper lens setting as shown in Figure A-9. If the camera is still out of focus after correcting the settings, the lens may need to be repaired or replaced. Notify the supervisor if this occurs.

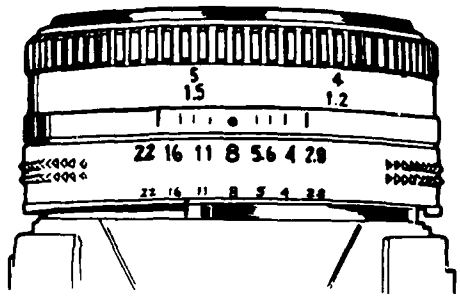

Figure A-9. Lens setting.

2. The film advance mode should be set on S (Figure A-10). If it requires adjusting, pull the knob up and turn (Figure A-11).

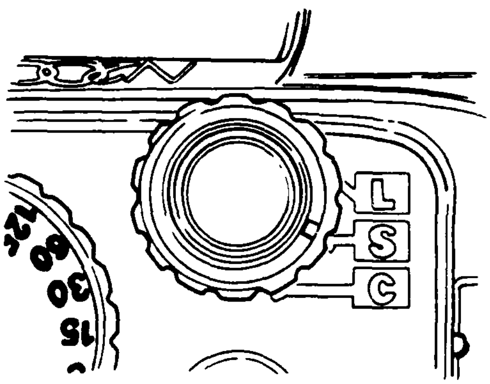

Figure A-10. Film advance mode.

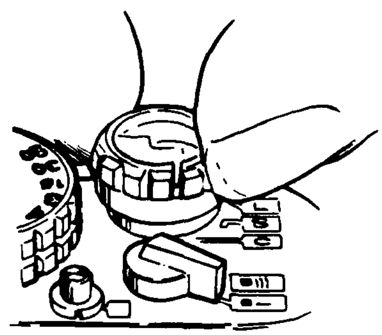

Figure A-11. Adjusting film advance mode.

3. The audible warning switch should be turned off, as shown in Figure A-12.

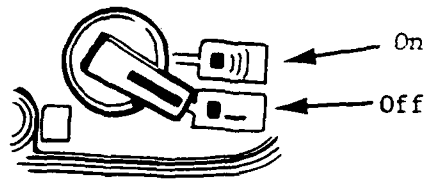

Figure A-12. Audible warning switch.

4. The shooting mode selector dial should be set on A (Figure A-13).

5. The film speed ring should be set at 400 (Figure A-14).

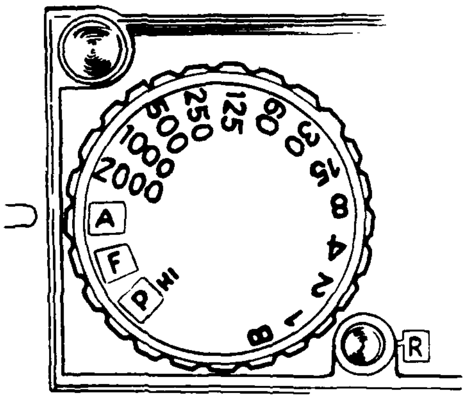

Figure A-13. Shooting mode selector.

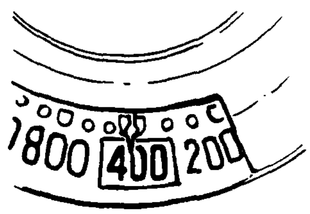

Figure A-14. Film speed ring.

6. The exposure compensation setting should be set at 0 (Figure A-15).

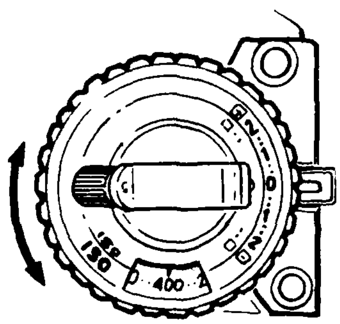

Figure A-15. Exposure compensation setting.

Loading Film

1. Open the camera back by pulling up on the film rewind knob until the camera back springs open (Figure A-16). See Figure A-17 for identification of parts inside the camera.

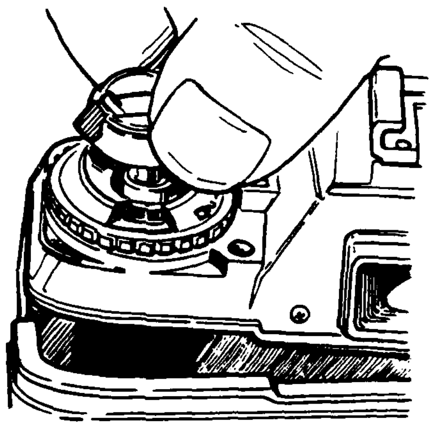

Figure A-16. Opening the camera.

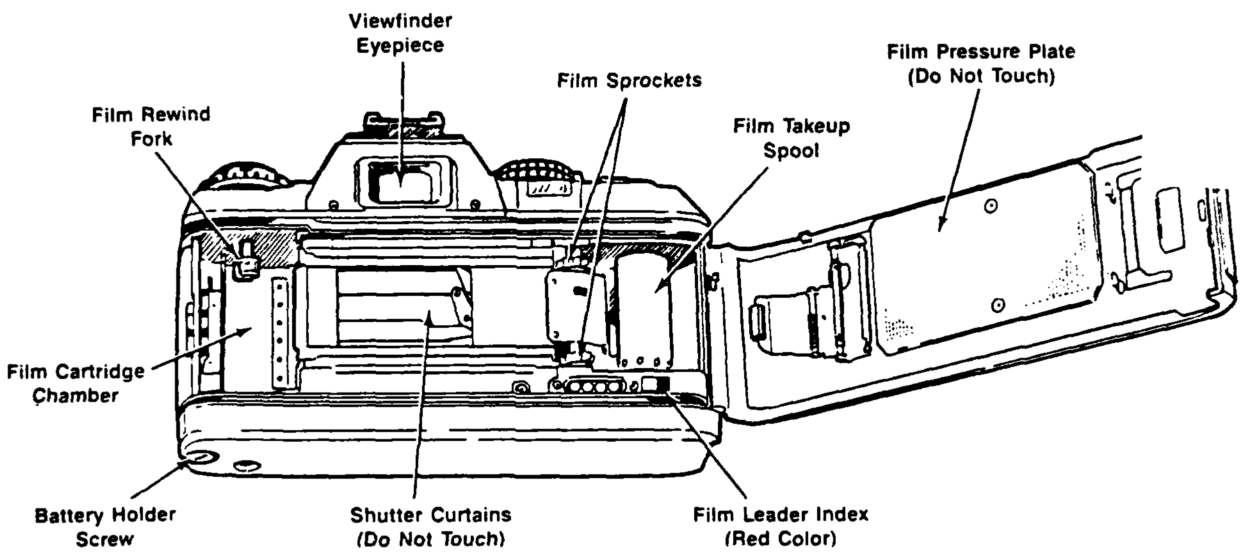

Figure A-17. Internal camera parts.

2. Position the film cartridge (see Figure A-18) so that the slotted end of the cartridge is at the top; lower the rewind knob.

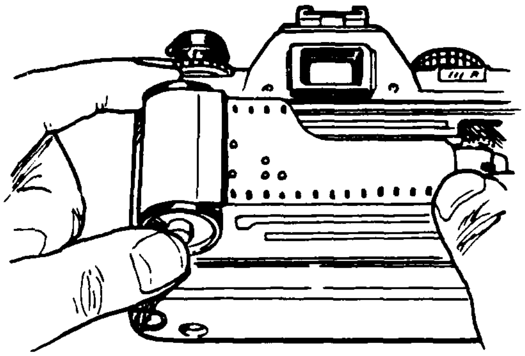

Figure A-18. Positioning the film cartridge.

3. Pull the film leader out to the red index mark (Figure A-19). There should be no slack in the film (Figure A-20).

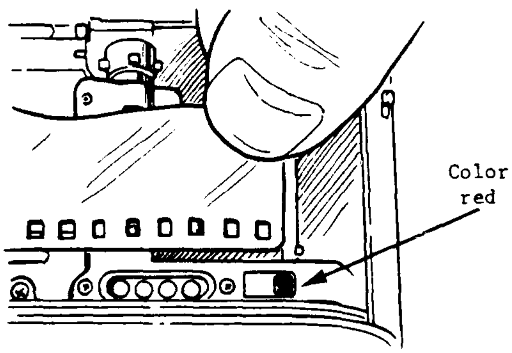

Figure A-19. Pulling out film leader.

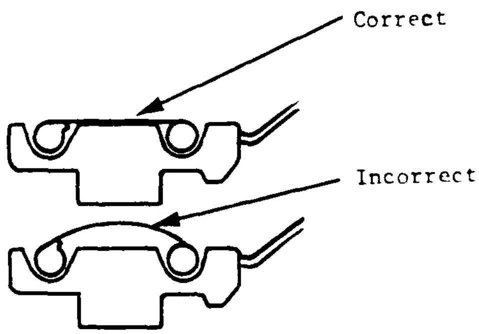

Figure A-20. Loading the film.

4. Close the back of the camera.

5. Press the top of the remote shutter release (Figure A-21) to automatically advance the film to frame "1" (Figure A-22).

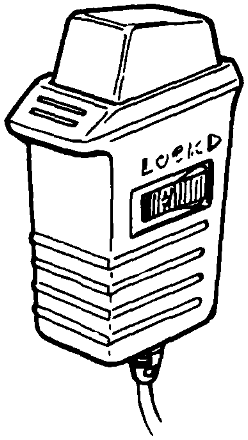

Figure A-21. Remote shutter release.

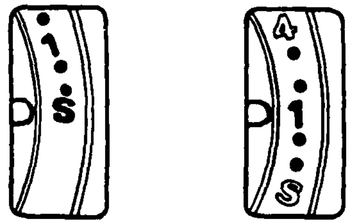

Figure A-22. Frame counter window.

Rewinding Film

When the film has been used up, the red indicator lamp (see Figure A-8) will flash. Rewind the film in the following way:

1. While sliding the film rewind lever to the right, push the film rewind button down (Figure A-23).

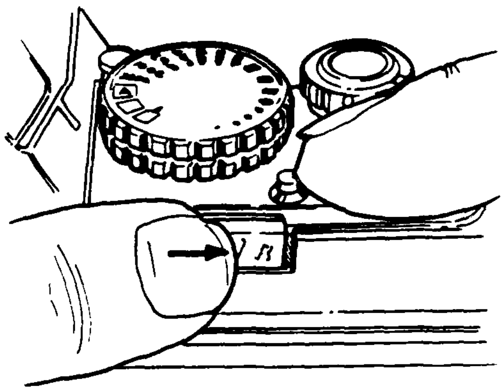

Figure A-23. Film rewind button and lever.

2. Fold out the film rewind crank and rotate it clockwise (Figure A-24) until the film advance indicator (Figure A-25) stops moving.

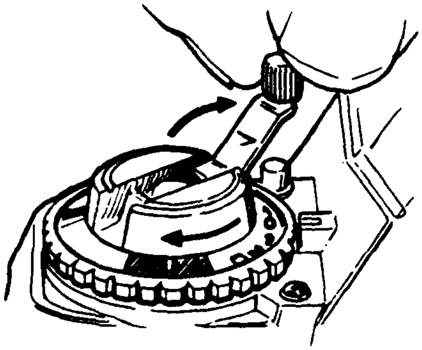

Figure A-24. Film rewind crank.

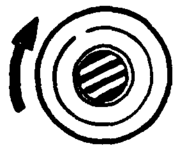

Figure A-25. Film advance indicator.

3. Pull up on the film rewind crank until the camera back springs open and remove film (Figure A-26).

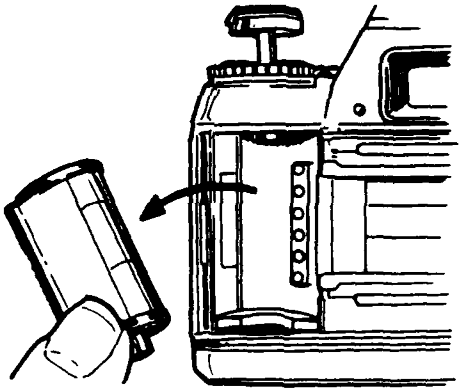

Figure A-26. Removing film.

Replacing Batteries

When the film advance begins to sound sluggish, it is time to change the batteries. This is done in the following way:

1. Use a quarter to remove the battery holder by turning the battery holder screw counterclockwise (Figure A-27).

2. Remove the bracket (Figure A-28).

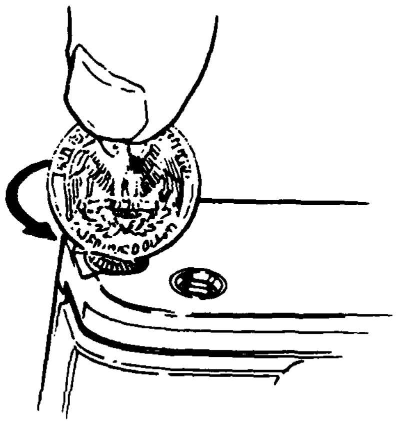

Figure A-27. Removing battery holder.

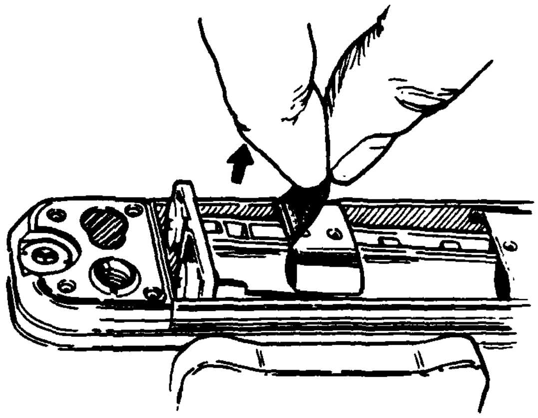

Figure A-28. Removing battery bracket.

3. Install four AAA-type batteries (Figure A-29).

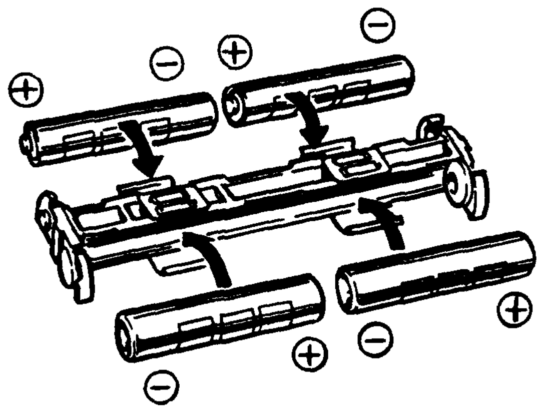

Figure A-29. Installing batteries.

4. Align the white dots and replace the bracket (Figure A-30).

5. Line up the hole in the bottom with the post in the camera base and reattach the battery holder (Figure A-31).

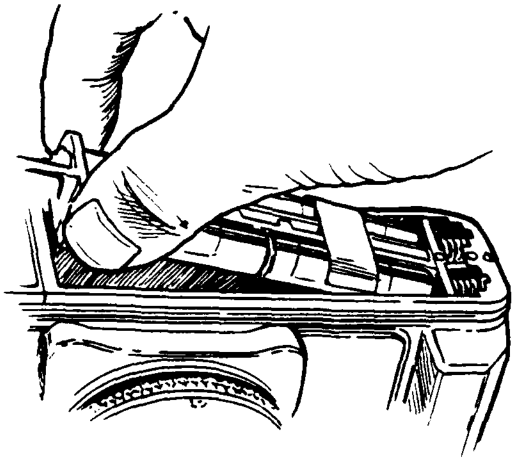

Figure A-30. Replacing battery bracket.

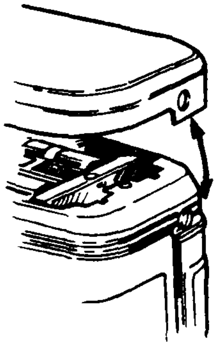

Figure A-31. Reattaching battery holder.

Precautions

1. Replace the view finder eyepiece cover (Figure A-32) whenever the camera is not in use.

2. Never touch the reflex mirror or focusing screen (Figure A-33).

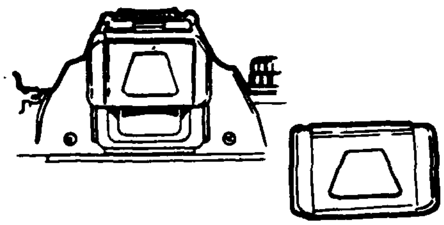

Figure A-32. Viewfinder eyepiece cover.

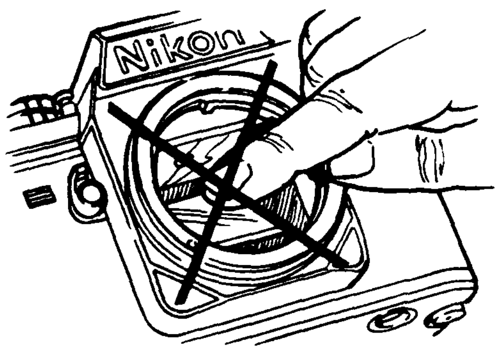

Figure A-33. Do not touch the reflex mirror.

3. Never touch the DX-contacts (Figure A-34).

4. Never touch the shutter curtains (Figure A-35).

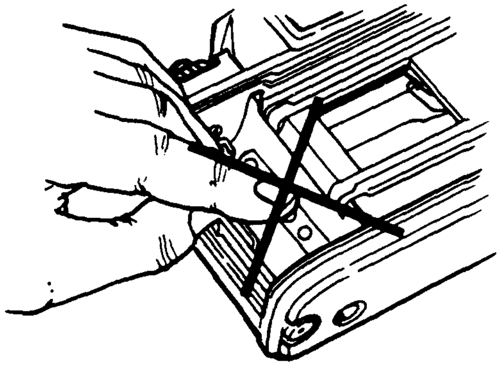

Figure A-34. Do not touch the DX-contacts.

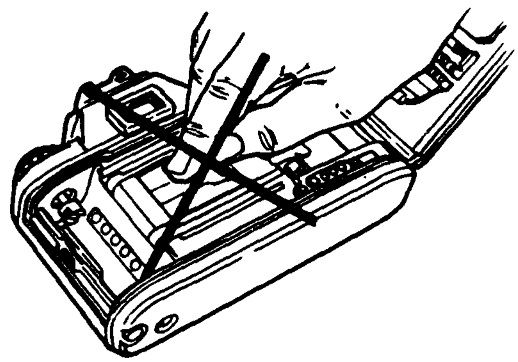

Figure A-35. Do not touch the shutter curtains.

MAINTENANCE

Unless the hand photometric system malfunctions, the only reason the device should be opened is to check for broken parts and to vacuum dust after shipping. The maintenance procedures to be followed when the device is shipped to a new location are as follows:

1. Remove the back of the device by using a 7/16-inch socket wrench.

2. Using a can of canned air (hold it vertically -- the slightest tilt of the can causes liquid to escape), dust off the mirror. CAUTION: The mirror is a very sensitive part of the mechanism and should not be touched.

3. Dust the remaining area (electronic components and floor) with a battery powered vacuum cleaner.

4. Replace the back panel; tightly secure bolts.

5. Check the camera settings (see section on camera instructions).

6. To ensure that the photobox is fully operational, use the Polaroid 35-mm Auto Processor (which is provided) to produce instant slides.

APPENDIX B

STEM LEAF GRAPHS OF DATA OBTAINED FROM TWO HAND-MEASURING METHODS

TABLE B-1. Hand Breadth.

PAPER MEASUREMENTS

MEAN = 8.81 STANDARD DEVIATION = 0.76

Stem	Leaf	Frequency
100	00000	5
98	000000000000	12
96	000000	6
94	000000000	9
92	0000000	7
90	0000000000000000	16
88	00000000	8
86	00000000000	11
84	00000000000000	14
82	0000000	7
80	000000000000	12
78	0000000	7
76	00	2
74		
72		
70		
68	00	2
66	00	2
64		
	TOTAL	60

Multiply stem leaf by 10**-01

SILHOUETTE MEASUREMENTS

MEAN = 8.92 STANDARD DEVIATION = 0.73

Stem	Leaf	Frequency
100	334	3
98	345577036667799999	18
96	3457891699	10
94	893	3
92	114557977	9
90	2558900799	10
88	045568936	9
86	0001224555692347	17
84	145582347	9
82	124449000022223788	18
80	59377	5
78	60667	5
76	9	1
74		
72		
70		
68	4	1
66	49	2
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE B-2. Digit 1 Breadth.

CALIPER MEASUREMENTS

MEAN = 2.12 STANDARD DEVIATION = 0.23

Stem	Leaf	Frequency
26	0000	4
25		
25	00	2
24		
24	000000000000	12
23		
23	000000000000000000000000	24
22		
22	000000000000	12
21		
21	0000000000000000	16
20		
20	000000000000000000000000000	27
19		
19	00000000	8
18		
18	000000	6
17		
17	0000000	7
16		
16	00	2
15		
	TOTAL	60

Multiply stem leaf by 10**-01

SILHOUETTE MEASUREMENTS

MEAN = 2.25 STANDARD DEVIATION = 0.23

Stem	Leaf	Frequency
27	79	2
27	01	2
26	79	2
26	12	2
25	557888	6
25	0001111	7
24	55566799	8
24	11122333333	11
23	78	2
23	0011344	7
22	5555667799	10
22	233333	6
21	55555777888899	14
21	0111113334	10
20	5666777799	10
20	133	3
19	5788	4
19	0033344	7
18	9	1
18	00333	5
17	6	1
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE B-3. Digit 2 Breadth.

CALIPER MEASUREMENTS

MEAN = 2.02 STANDARD DEVIATION = 0.20

Stem	Leaf	Frequency
24	000	3
23		
23	00000000000000000	17
22		
22	000000000000	12
21		
21	000000000000000000000	21
20		
20	0000000000000000000000000	25
19		
19	000000000000000000	18
18		
18	0000000000000	13
17		
17	0000000	7
16		
16	000	3
15		
15	0	1
14		
	TOTAL	60

Multiply stem leaf by 10**-01

SILHOUETTE MEASUREMENTS

MEAN = 2.17 STANDARD DEVIATION = 0.21

Stem	Leaf	Frequency
25	00011	5
24	55556777799	11
24	1111233	7
23	57789	5
23	01111444	8
22	56677799	8
22	11123333	8
21	555777777789	12
21	0000111133344444	16
20	5667777799	10
20	1112222	7
19	55789	5
19	0011334	7
18	7799	4
18	02	2
17	9	1
17	11	2
16	78	2
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE B-4. Digit 3 Breadth.

CALIPER MEASUREMENTS

MEAN = 2.00 STANDARD DEVIATION = 0.21

Stem	Leaf	Frequency
24	0	1
23		
23	0000000000000000000	19
22		
22	0000000000	10
21		
21	0000000000	10
20		
20	00000000000000000000000000000000000000	38
19		
19	00000000000000	14
18		
18	000000000000000	15
17		
17	000000000	9
16		
16		
15		
15	000	3
14		
14	0	1
13		
	TOTAL	60

Multiply stem leaf by 10**-01

SILHOUETTE MEASUREMENTS

MEAN = 2.15 STANDARD DEVIATION = 0.21

Stem	Leaf	Frequency
25	0014	4
24	66799	5
24	1113333333	10
23	888899	6
23	00344	5
22	5666777	7
22	111112233	9
21	5777778899	10
21	00011111113444444	17
20	5555567777799	13
20	3333	4
19	5577788	7
19	1133333334444	13
18	779	3
18	03	2
17	9	1
17		
16	66	2
16	2	1
15	8	1
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE B-5. Digit 4 Breadth.

CALIPER MEASUREMENTS

MEAN = 1.86 STANDARD DEVIATION = 0.21

Stem	Leaf	Frequency
22	000000000	9
21		
21	000000000000000	15
20		
20	00000000000000000000	20
19		
19	000000000000000	15
18		
18	000000000000000000000	21
17		
17	000000000000000000000000	24
16		
16	00000000000	11
15		
15	0	1
14		
14	0000	4
13		
	TOTAL	60

Multiply stem leaf by 10**-01

SILHOUETTE MEASUREMENTS

MEAN = 2.00 STANDARD DEVIATION = 0.21

Stem	Leaf	Frequency
23	7	1
23	000133	6
22	555566677999	12
22	11223333	8
21	7788899	7
21	0011144	7
20	5567779999	10
20	111111333	9
19	555777888	9
19	11113334444	11
18	55566679999	11
18	01223	5
17	5677888899	10
17	0111234	7
16	78	2
16	3	1
15		
15	012	3
14	8	1
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE B-6. Digit 5 Breadth.

CALIPER MEASUREMENTS

MEAN = 1.62 STANDARD DEVIATION = 0.19

Stem	Leaf	Frequency
20	0000000	7
19		
19	000000000	9
18		
18	0000000000000	13
17		
17	0000000000000000	16
16		
16	0000000000000000000000000000000	31
15		
15	000000000000000000000000	24
14		
14	000000000	9
13		
13	00000000	8
12		
12	000	3
11		
	TOTAL	60

Multiply stem leaf by 10**-01

SILHOUETTE MEASUREMENTS

MEAN = 1.73 STANDARD DEVIATION = 0.18

Stem	Leaf	Frequency
22	2	1
21		
21	0	1
20	55677	5
20	1112	4
19	56777888	8
19	11344	5
18	5556679	7
18	000113333	9
17	555567789	9
17	00001111111111122444	20
16	6777889	7
16	02222233444	11
15	55556666888899999	17
15	12224	5
14	7778888	7
14	02	2
13	55	2
13		
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE B-7. Hand Length.

PAPER MEASUREMENTS

MEAN =18.97 STANDARD DEVIATION = 1.63

Stem	Leaf	Frequency
23	6	1
23	244	3
22		
22		
21		
21	001	3
20	5556666777778999	16
20	00133444	8
19	5567778889999	13
19	00000111223344	14
18	5556667777889999	16
18	0001112222334	13
17	556667788888888999	18
17	11223334444	11
16		
16		
15		
15		
14	55	2
14	11	2
	TOTAL	60

SILHOUETTE MEASUREMENTS

MEAN = 18.93 STANDARD DEVIATION = 1.55

Stem	Leaf	Frequency
23	013	3
22	9	1
22		
21		
21	1	1
20	55566677777999	14
20	112233333333	12
19	555668888999	12
19	00000111114	11
18	667777778888888	15
18	000000002223334444444	21
17	55555666668889999	17
17	124444444	9
16		
16		
15		
15		
14	66	2
14	34	2
	TOTAL	60

TABLE B-8. Digit 1 Length.

PAPER MEASUREMENTS

MEAN = 5.80 STANDARD DEVIATION = 0.51

Stem	Leaf	Frequency
71	0	1
70	0	1
69	000	3
68		
67		
66	0000	4
65	00000	5
64	000	3
63	000	3
62	000000	6
61	0000000000	10
60	00000000000	11
59	00000	5
58	0000000000	10
57	000000000	9
56	00000000000	11
55	0000000000000	13
54	0000	4
53	0000	4
52	0000000	7
51	000	3
50	000	3
49		
48		
47	00	2
46	0	1
45	0	1
44		
	TOTAL	60

Multiply stem leaf by 10**-01

SILHOUETTE MEASUREMENTS

MEAN = 5.73 STANDARD DEVIATION = 0.49

Stem	Leaf	Frequency
69	01	2
68	23	2
67	3	1
66		
65	59	2
64	3	1
63	45568	5
62	0078	4
61	0244689	7
60	22346667	8
59	0012456689	10
58	0000124446	10
57	0011122258889999	16
56	333446888	9
55	01144888889	11
54	1457	4
53	1226	4
52	11447	5
51	13557777999	11
50	458	3
49	5	1
48		
47		
46		
45		
44	7	1
43	299	3
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE B-9. Digit 2 Length.

PAPER MEASUREMENTS			SILHOUETTE MEASUREMENTS		
MEAN = 7.47	STANDARD DEVIATION = 0.53		MEAN = 7.51	STANDARD DEVIATION = 0.52	
Stem	Leaf	Frequency	Stem	Leaf	Frequency
88	0	1	88	2	1
86	000	3	86	992	3
84			84		
82	000	3	82	144	3
80	000000000000	12	80	0259003677	10
78	0000000000	10	78	2222592366689	13
76	0000000000000000000000000000000	31	76	22333355556791135558888	23
74	00000000000	11	74	35566679990134578889	20
72	00000000000000000000	20	72	112355779990001355	18
70	0000000000000000	16	70	25566990111445588	17
68	000000000	9	68	4444799	7
66			66	7	1
64			64		
62			62		
60			60		
58	00	2	58	261	3
56	00	2	56	8	1
	TOTAL	60		TOTAL	60

Multiply stem leaf by 10**-01

Multiply stem leaf by 10**-01

TABLE B-10. Digit 3 Length.

PAPER MEASUREMENTS

MEAN = 8.19 STANDARD DEVIATION = 0.67

Stem	Leaf	Frequency
100	0	1
98	000	3
96		
94		
92	00	2
90	0000000	7
88	00000	5
86	0000000000000000	16
84	0000000000	10
82	00000000000000	14
80	00000000000000000000	20
78	000000000000000000	18
76	000000000000	12
74	0000000	7
72		
70	0	1
68		
66		
64		
62	0	1
60	000	3
	TOTAL	60

Multiply stem leaf by 10**-01

SILHOUETTE MEASUREMENTS

MEAN = 8.26 STANDARD DEVIATION = 0.65

Stem	Leaf	Frequency
98	3535	4
96		
94		
92	388	3
90	00902239	8
88	025478	6
86	11245568993478	14
84	045034778	9
82	001446666023346688	18
80	112455566688990237	18
78	225556000022678	15
76	11356799011334588899	20
74	9	1
72		
70		
68		
66		
64		
62	2228	4
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE B-11. Digit 4 Length.

PAPER MEASUREMENTS

MEAN = 7.30 STANDARD DEVIATION = 0.66

Stem	Leaf	Frequency
88	00	2
86	00	2
84	0000	4
82	0000000000	10
80	00000	5
78	0	1
76	00000	5
74	000000000000000000	18
72	00000000000000000000	20
70	00000000000000	14
68	00000000000000000000000000	26
66	000000000	9
64		
62		
60		
58		
56		
54	00	2
52	00	2
	TOTAL	60

Multiply stem leaf by 10**-01

SILHOUETTE MEASUREMENTS

MEAN = 7.37 STANDARD DEVIATION = 0.65

Stem	Leaf	Frequency
88	46	2
86	90	2
84	1155647	7
82	12948	5
80	0603	4
78	125622	6
76	12556675888999	14
74	56679914555777	14
72	336755577	9
70	0112556699001188999	19
68	1122233557790111333355555889	28
66	91588	5
64	6	1
62		
60		
58		
56		
54	5249	4
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE B-12. Digit 5 Length.

PAPER MEASUREMENTS

MEAN = 5.75 STANDARD DEVIATION = 0.59

Stem	Leaf	Frequency
70	000000	6
68	00	2
66	000	3
64	0000000	7
62	0000000000000	13
60	00000000	8
58	0000000000000000	16
56	0000000000000000000	19
54	000000000000000000000	21
52	0000000	7
50	00000000000000	14
48		
46		
44		
42	000	3
40	0	1
	TOTAL	60

Multiply stem leaf by 10**-01

SILHOUETTE MEASUREMENTS

MEAN = 5.82 STANDARD DEVIATION = 0.58

Stem	Leaf	Frequency
72	36	2
70	1791	4
68	69	2
66	2	1
64	000344611456	12
62	2312559	7
60	0022266781145	13
58	0446800111244468	16
56	233444677800222256689	21
54	1455888801224588999	19
52	3578889117	10
50	811133	6
48	399	3
46		
44		
42	8357	4
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE B-13. Crotch 1 Height.

PAPER MEASUREMENTS

MEAN = 6.72 STANDARD DEVIATION = 0.81

Stem	Leaf	Frequency
96	000	3
94		
92		
90	0	1
88		
86		
84		
82		
80		
78	0	1
76	00	2
74	000000	6
72	00000000000000000	17
70	000000000000000000	18
68	00000000000000	14
66	00000000	8
64	0000000000	10
62	000000000000000	15
60	000000000	9
58	00000	5
56	00000	5
54	00	2
52	0	1
50	0	1
48	00	2
46		
	TOTAL	60

Multiply stem leaf by 10**-01

SILHOUETTE MEASUREMENTS

MEAN = 6.83 STANDARD DEVIATION = 0.81

Stem	Leaf	Frequency
98	9	1
96		
94	23	2
92	3	1
90		
88		
86		
84		
82		
80		
78	572	3
76	5609	4
74	555670045778	12
72	351355788899	12
70	3559345799	10
68	79001135599	11
66	012239913345577888	18
64	0267714599	10
62	0346677888004	13
60	02344671269	11
58	845	3
56	1268	4
54	1	1
52	7	1
50	441	3
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE B-14. Crotch 2 Height.

PAPER MEASUREMENTS

MEAN =10.830 STANDARD DEVIATION = 1.040

Stem	Leaf	Frequency
13	568	3
13	4	1
12		
12	000011133	9
11	5556777777777888888899999	25
11	00112444	8
10	55555555556666667777778889999999	32
10	00000011111111122223333333	26
9	77888899	8
9	2344	4
8		
8	0033	4
7		
	TOTAL	60

SILHOUETTE MEASUREMENTS

MEAN = 10.84 STANDARD DEVIATION = 1.00

Stem	Leaf	Frequency
13	59	2
13	24	2
12		
12	11123333	8
11	5555666677777778888999999	25
11	111224444	9
10	5555666677777777888888889999	28
10	0000111111111222222233344444	28
9	56667778888888	14
9		
8		
8	3444	4
	TOTAL	60

TABLE B-15. Crotch 3 Height.

PAPER MEASUREMENTS

MEAN =10.78 STANDARD DEVIATION = 1.05

Stem	Leaf	Frequency
13	7789	4
13		
12		
12	011	3
11	55666666677777777788888999999	29
11	000011233444	12
10	5555556666677788888999999	25
10	000000011122222333444444	24
9	55555677888999999	17
9	44	2
8		
8	22	2
7	99	2
	TOTAL	60

SILHOUETTE MEASUREMENTS

MEAN = 10.71 STANDARD DEVIATION = 1.01

Stem	Leaf	Frequency
14	0	1
13	55	2
13	3	1
12		
12	0012	4
11	55555566666777777789999	23
11	0011111333444	13
10	555555566666677777777888999	27
10	000011222223333344444	21
9	556667777777888889999	21
9	223	3
8		
8	2334	4
	TOTAL	60

TABLE B-16. Crotch 4 Height.

PAPER MEASUREMENTS

MEAN = 9.52 STANDARD DEVIATION = 1.01

Stem	Leaf	Frequency
12	6679	4
12		
11		
11	00	2
10	55556667777789	14
10	1112222222333444	16
9	5555556666677777778999	22
9	0011111112222223334444	22
8	5666666777777888888888899999999	31
8	11334	5
7	5	1
7	113	3
	TOTAL	60

SILHOUETTE MEASUREMENTS

MEAN = 9.36 STANDARD DEVIATION = 1.00

Stem	Leaf	Frequency
12	8	1
12	134	3
11		
11	1	1
10	55566677788	11
10	11222223333334	14
9	555666667788889	15
9	000000001111122222223333444444444	33
8	5555666677777778888899	22
8	001223334444444	15
7	67	2
7	234	3
	TOTAL	60

APPENDIX C

STEM LEAF GRAPHS SHOWING RESULTS OF INTERTRIAL DIFFERENCES OBTAINED IN TWO HAND-MEASURING METHODS

TABLE C-1. Hand Breadth.

PAPER MEASUREMENTS

MEAN = 0.09   STANDARD DEVIATION = 0.08

Stem	Leaf	Frequency
30	000	3
28		
26		
24		
22		
20	00000000	8
18		
16		
14		
12		
10	000000000000000000000000000000	30
8		
6		
4		
2		
0	0000000000000000000	19
	TOTAL	60

Multiply stem leaf by 10**-02

SILHOUETTE MEASUREMENTS

MEAN = 0.09   STANDARD DEVIATION = 0.08

Stem	Leaf	Frequency
36	0	1
34		
32		
30	00	2
28		
26		
24		
22	00	2
20	0	1
18	0	1
16	00000	5
14	000	3
12	00000	5
10	000000	6
8	00	2
6	00000000	8
4	0000000	7
2	00000000	8
0	000000000	9
	TOTAL	60

Multiply stem leaf by 10**-02

TABLE C-2. Digit 1 Breadth.

CALIPER MEASUREMENTS

MEAN = 0.03 STANDARD DEVIATION = 0.04

Stem	Leaf	Frequency
10	000000000000000	15
9		
9		
8		
8		
7		
7		
6		
6		
5		
5		
4		
4		
3		
3		
2		
2		
1		
1		
0		
0	000000000000000000000000000000000000000000000	45
	TOTAL	60

Multiply stem leaf by 10**-02

SILHOUETTE MEASUREMENTS

MEAN = 0.05 STANDARD DEVIATION = 0.04

Stem	Leaf	Frequency
18	00	2
17		
16		
15		
14	00	2
13		
12	00	2
11	00	2
10		
9	000	3
8	00000000	8
7	0000	4
6	00	2
5	0000	4
4	000000000	9
3	00000	5
2	000	3
1	00000000	8
0	000000	6
	TOTAL	60

Multiply stem leaf by 10**-02

TABLE C-3. Digit 2 Breadth.

CALIPER MEASUREMENTS

MEAN = 0.03 STANDARD DEVIATION = 0.05

Stem	Leaf	Frequency
20	00	2
19		
18		
17		
16		
15		
14		
13		
12		
11		
10	00000000000000	14
9		
8		
7		
6		
5		
4		
3		
2		
1		
0	00000000000000000000000000000000000000000000	44
	TOTAL	60

Multiply stem leaf by 10**-02

SILHOUETTE MEASUREMENTS

MEAN = 0.04 STANDARD DEVIATION = 0.04

Stem	Leaf	Frequency
19	0	1
18		
17		
16		
15		
14	0	1
13		
12		
11	0	1
10	0	1
9	0	1
8	00	2
7	00	2
6	000000	6
5	00000	5
4	000000000000	12
3	0000000000	10
2	0000	4
1	00000000	8
0	000000	6
	TOTAL	60

Multiply stem leaf by 10**-02

TABLE C-4. Digit 3 Breadth.

CALIPER MEASUREMENTS

MEAN = 0.02 STANDARD DEVIATION = 0.04

Stem	Leaf	Frequency
1	00000000000	11
.		
.		
.		
.		
.		
.		
.		
.		
.		
.		
.		
.		
.		
.		
.		
0	0000000000000000000000000000000000000000000000000	49
	TOTAL	60

SILHOUETTE MEASUREMENTS

MEAN = 0.04 STANDARD DEVIATION = 0.04

Stem	Leaf	Frequency
17	0	1
16	00	2
15	0	1
14		
13		
12		
11	0	1
10		
9		
8	00	2
7	00000	5
6	00	2
5	000000	6
4	000000000	9
3	0000000	7
2	00000000	8
1	00000000	8
0	00000000	8
	TOTAL	60

Multiply stem leaf by 10**-02

TABLE C-5. Digit 4 Breadth.

CALIPER MEASUREMENTS

MEAN = 0.03   STANDARD DEVIATION = 0.05

Stem	Leaf	Frequency
20	0	1
19		
18		
17		
16		
15		
14		
13		
12		
11		
10	0000000000000	13
9		
8		
7		
6		
5		
4		
3		
2		
1		
0	0000000000000000000000000000000000000000000000	46
	TOTAL	60

Multiply stem leaf by 10**-02

SILHOUETTE MEASUREMENTS

MEAN = 0.05   STANDARD DEVIATION = 0.04

Stem	Leaf	Frequency
17	0	1
16		
15		
14	00	2
13	0	1
12	00	2
11	0	1
10		
9	000	3
8	0000	4
7	000	3
6	00000	5
5	0000	4
4	0000000	7
3	0000000	7
2	000000	6
1	0000000	7
0	0000000	7
	TOTAL	60

Multiply stem leaf by 10**-02

TABLE C-6. Digit 5 Breadth.

CALIPER MEASUREMENTS

MEAN = 0.03 STANDARD DEVIATION = 0.05

Stem	Leaf	Frequency
20	0	1
19		
18		
17		
16		
15		
14		
13		
12		
11		
10	00000000000000000	17
9		
8		
7		
6		
5		
4		
3		
2		
1		
0	000000000000000000000000000000000000000000	42
	TOTAL	60

Multiply stem leaf by 10**-02

SILHOUETTE MEASUREMENTS

MEAN = 0.04 STANDARD DEVIATION = 0.04

Stem	Leaf	Frequency
20	0	1
19		
18	0	1
17		
16		
15	0	1
14		
13		
12	0	1
11		
10	00	2
9	0	1
8	00	2
7	00	2
6	0000	4
5	000	3
4	00000	5
3	00000000	8
2	00000000	8
1	00000000000	11
0	0000000000	10
	TOTAL	60

Multiply stem leaf by 10**-02

TABLE C-7. Hand Length.

PAPER MEASUREMENTS

MEAN = 0.13 STANDARD DEVIATION = 0.10

Stem	Leaf	Frequency
40	0	1
38		
36		
34		
32		
30	00000	5
28		
26		
24		
22		
20	0000000000000000	16
18		
16		
14		
12		
10	000000000000000000000000	24
8		
6		
4		
2		
0	00000000000000	14
	TOTAL	60

Multiply stem leaf by 10**-02

SILHOUETTE MEASUREMENTS

MEAN = 0.17 STANDARD DEVIATION = 0.18

Stem	Leaf	Frequency
54	0	1
52		
50		
48		
46		
44		
42		
40	00000	5
38		
36		
34		
32		
30		
28	0	1
26	00000000000000000	17
24		
22		
20		
18		
16		
14	0000000	7
12	000000000000000	15
10		
8		
6		
4		
2		
0	00000000000000	14
	TOTAL	60

Multiply stem leaf by 10**-02

TABLE C-8. Digit 1 Length.

PAPER MEASUREMENTS

MEAN = 0.14 STANDARD DEVIATION = 0.13

Stem	Leaf	Frequency
50	00	2
48		
46		
44		
42		
40	00	2
38		
36		
34		
32		
30	000000	6
28		
26		
24		
22		
20	00000000000000	14
18		
16		
14		
12		
10	000000000000000000000	21
8		
6		
4		
2		
0	000000000000000	15
	TOTAL	60

Multiply stem leaf by 10**-02

SILHOUETTE MEASUREMENTS

MEAN = 0.10 STANDARD DEVIATION = 0.09

Stem	Leaf	Frequency
38	0	1
36	0	1
34	0	1
32		
30		
28		
26		
24	0	1
22	00	2
20	00	2
18		
16	000	3
14	000	3
12	0000	4
10	00000	5
8	000000000	9
6	000000	6
4	0000000	7
2	0000000	7
0	00000000	9
	TOTAL	60

Multiply stem leaf by 10**-02

TABLE C-9. Digit 2 Length.

PAPER MEASUREMENTS

MEAN = 0.08 STANDARD DEVIATION = 0.09

Stem	Leaf	Frequency
40	0	1
38		
36		
34		
32		
30	0	1
28		
26		
24		
22		
20	00000000	8
18		
16		
14		
12		
10	000000000000000000000000000	27
8		
6		
4		
2		
0	00000000000000000000000	23
	TOTAL	60

Multiply stem leaf by 10**-02

SILHOUETTE MEASUREMENTS

MEAN = 0.08 STANDARD DEVIATION = 0.06

Stem	Leaf	Frequency
22	0	1
21		
20	00	2
19	0	1
18	0	1
17	00	2
16	0	1
15	0	1
14		
13	00	2
12	00000	5
11	0	1
10		
9	000	3
8	000000	6
7	00000	5
6		
5	00000	5
4	00000000	8
3	00000	5
2	000000	6
1	0	1
0	0000	4
	TOTAL	60

Multiply stem leaf by 10**-02

TABLE C-10. Digit 3 Length.

PAPER MEASUREMENTS

MEAN = 0.05 STANDARD DEVIATION = 0.07

Stem	Leaf	Frequency
40	0	1
38		
36		
34		
32		
30		
28		
26		
24		
22		
20	0	1
18		
16		
14		
12		
10	00000000000000000000000	23
8		
6		
4		
2		
0	00000000000000000000000000000000000	35
	TOTAL	60

Multiply stem leaf by 10**-02

SILHOUETTE MEASUREMENTS

MEAN = 0.06 STANDARD DEVIATION = 0.05

Stem	Leaf	Frequency
19	0	1
18		
17	0	1
16	0000	4
15	0	1
14	0	1
13	0	1
12		
11		
10	000	3
9	000	3
8	00	2
7	00000	5
6	0000000	7
5	00000000	8
4	0000000	7
3	0000	4
2	00000	5
1	000	3
0	0000	4
	TOTAL	60

Multiply stem leaf by 10**-02

TABLE C-11. Digit 4 Length.

PAPER MEASUREMENTS

MEAN = 0.07 STANDARD DEVIATION = 0.08

Stem	Leaf	Frequency
30	00	2
28		
26		
24		
22		
20	000000	6
18		
16		
14		
12		
10	0000000000000000000000000	25
8		
6		
4		
2		
0	000000000000000000000000000	27
	TOTAL	60

Multiply stem leaf by 10**-02

SILHOUETTE MEASUREMENTS

MEAN = 0.06 STANDARD DEVIATION = 0.05

Stem	Leaf	Frequency
19	0	1
18		
17		
16	0	1
15	0	1
14	00	2
13	000	3
12	0	1
11	0	1
10	0000	4
9	0	1
8	00000	5
7	0000	4
6	0000	4
5	000	3
4	000000	6
3	000000000	9
2	000000	6
1	000	3
0	00000	5
	TOTAL	60

Multiply stem leaf by 10**-02

TABLE C-12. Digit 5 Length.

PAPER MEASUREMENTS

MEAN = 0.08 STANDARD DEVIATION = 0.08

Stem	Leaf	Frequency
40	0	1
38		
36		
34		
32		
30	0	1
28		
26		
24		
22		
20	000	3
18		
16		
14		
12		
10	00000000000000000000000000000000	32
8		
6		
4		
2		
0	00000000000000000000000	23
	TOTAL	60

Multiply stem leaf by 10**-02

SILHOUETTE MEASUREMENTS

MEAN = 0.06 STANDARD DEVIATION = 0.05

Stem	Leaf	Frequency
19	00	2
18	0	1
17		
16		
15		
14	0	1
13	00	2
12	00	2
11	00	2
10	0	1
9	0000	4
8	00000	5
7	000	3
6	00000	5
5	00	2
4	00000	5
3	0000000000	10
2	0000000	7
1	00000	5
0	000	3
	TOTAL	60

Multiply stem leaf by 10**-02

TABLE C-13. Crotch 1 Height.

PAPER MEASUREMENTS

MEAN = 0.18 STANDARD DEVIATION = 0.16

Stem	Leaf	Frequency
7	0	1
6		
6	0	1
5		
5	00000	5
4		
4	00	2
3		
3	0	1
2		
2	000000000000000000	18
1		
1	0000000000000000000000	22
0		
0	0000000000	10
	TOTAL	60

Multiply stem leaf by 10**-01

SILHOUETTE MEASUREMENTS

MEAN = 0.24 STANDARD DEVIATION = 0.17

Stem	Leaf	Frequency
7	7	1
7	1	1
6		
6	4	1
5	5	1
5	0	1
4	8	1
4	02224	5
3	6689	4
3	2	1
2	6666789	7
2	000334	6
1	5666778889999999	16
1	4	1
0	5567889	7
0	0012234	7
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE C-14. Crotch 2 Height.

PAPER MEASUREMENTS

MEAN = 0.12 STANDARD DEVIATION = 0.09

Stem	Leaf	Frequency
30	00000	5
28		
26		
24		
22		
20	0000000000000	13
18		
16		
14		
12		
10	0000000000000000000000000000	28
8		
6		
4		
2		
0	00000000000000	14
	TOTAL	60

Multiply stem leaf by 10**-02

SILHOUETTE MEASUREMENTS

MEAN = 0.16 STANDARD DEVIATION = 0.13

Stem	Leaf	Frequency
5	9	1
5		
4	7	1
4	11	2
3	569	3
3	03	2
2	58	2
2	0122344	7
1	6667778899	10
1	001223344	9
0	5566677777888	13
0	0223344444	10
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE C-15. Crotch 3 Height.

PAPER MEASUREMENTS

MEAN = 0.14 STANDARD DEVIATION = 0.12

Stem	Leaf	Frequency
50	0	1
48		
46		
44		
42		
40	0	1
38		
36		
34		
32		
30	0000000000	10
28		
26		
24		
22		
20	0000000000000	13
18		
16		
14		
12		
10	0000000000000000000	19
8		
6		
4		
2		
0	0000000000000000	16
	TOTAL	60

Multiply stem leaf by 10**-02

SILHOUETTE MEASUREMENTS

MEAN = 0.20 STANDARD DEVIATION = 0.15

Stem	Leaf	Frequency
6	4	1
5		
5		
4	779	3
4	34	2
3	55669	5
3	0011123	7
2	5566689	7
2	1114	4
1	5666	4
1	12223333	8
0	55788899	8
0	01122224444	11
	TOTAL	60

Multiply stem leaf by 10**-01

TABLE C-16. Crotch 4 Height.

PAPER MEASUREMENTS

MEAN = 0.20 STANDARD DEVIATION = 0.16

Stem	Leaf	Frequency
6	00	2
5		
5	000	3
4		
4	000000	6
3		
3	000000000	9
2		
2	00000000000	11
1		
1	0000000000000000000	19
0		
0	0000000000	10
	TOTAL	60

Multiply stem leaf by 10**-01

SILHOUETTE MEASUREMENTS

MEAN = 0.24 STANDARD DEVIATION = 0.18

Stem	Leaf	Frequency
7	55	2
7		
6		
6		
5	9	1
5	0	1
4	68	2
4	0000133	7
3	666679	6
3	012	3
2	5688	4
2	011344	6
1	578	3
1	00123444444	11
0	55778899	8
0	111134	6
	TOTAL	60

Multiply stem leaf by 10**-01

APPENDIX D

MULTIPLE ANALYSIS OF VARIANCE (MANOVA) RESULTS

TABLE D-1. Hand and Digit Breadths.

INTERACTION EFFECT OF INVESTIGATOR AND METHOD

CHARAC-TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR V'EV=1 Hand Breadth	Digit 1 Breadth	Digit 2 Breadth	Digit 3 Breadth	Digit 4 Breadth	Digit 5 Breadth
0.1016	100.00	0.0153	-0.5448	-0.0348	-0.1373	0.6797	0.1388

HOTELLING-LAWLEY TRACE = 0.1016 $F(6,231) = 3.91$

PROB > F = 0.0010

TABLE D-2. Hand and Digit Breadths by Investigators.

INVESTIGATOR 1

CHARAC-TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR V'EV=1 Hand Breadth	Digit 1 Breadth	Digit 2 Breadth	Digit 3 Breadth	Digit 4 Breadth	Digit 5 Breadth
0.6132	100.00	-0.2564	0.2960	0.1760	0.8827	-0.2828	-0.0453

HOTELLING-LAWLEY TRACE = 0.6132 F(6,231) = 11.55

PROB > F = 0.0001

INVESTIGATOR 2

CHARAC-TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR V'EV=1 Hand Breadth	Digit 1 Breadth	Digit 2 Breadth	Digit 3 Breadth	Digit 4 Breadth	Digit 5 Breadth
0.6038	100.00	-0.1804	-0.4240	0.4022	0.3008	0.5336	0.0738

HOTELLING-LAWLEY TRACE = 0.6038 F(6,231) = 11.37

PROB > F = 0.0001

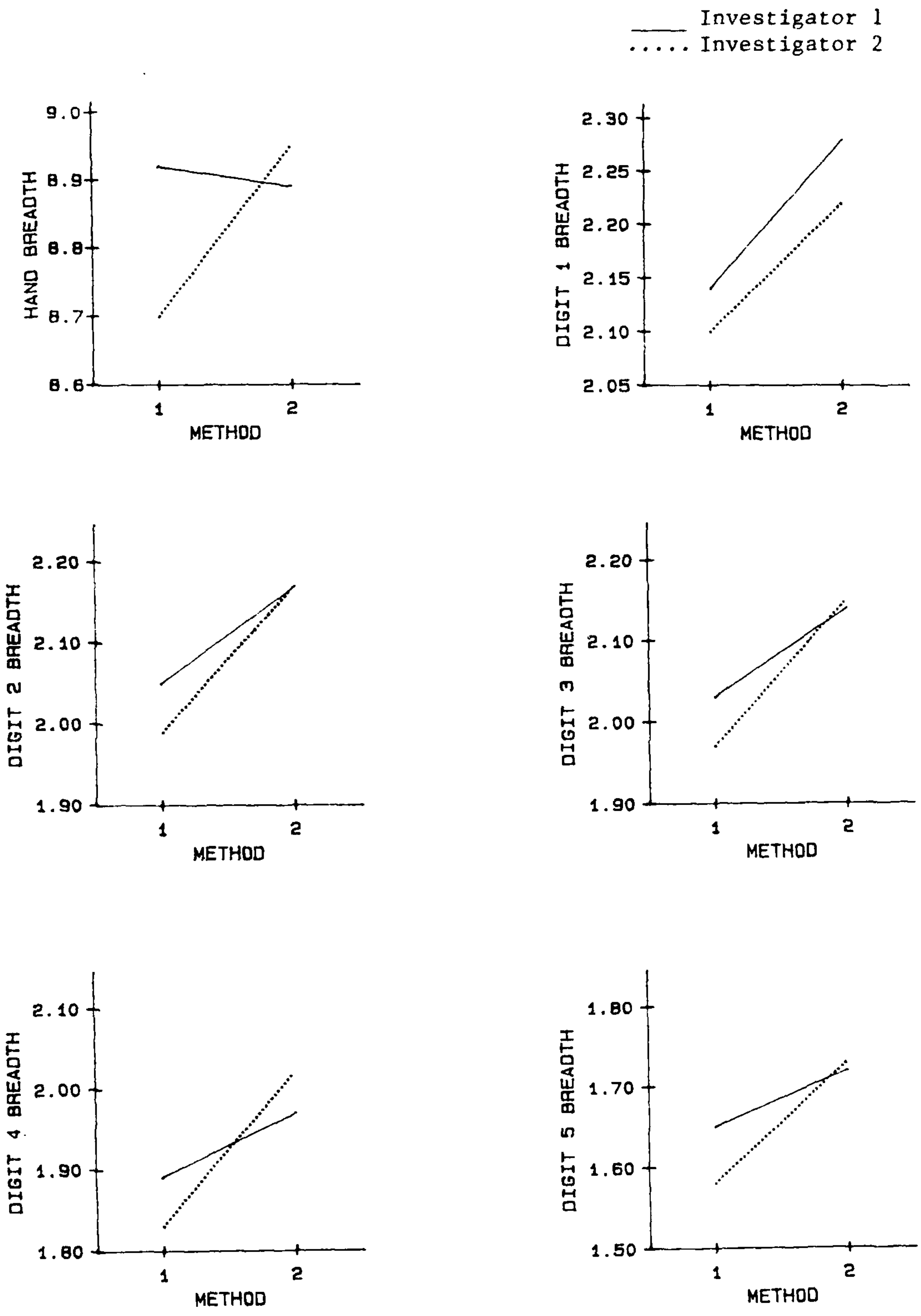

Figure D-1. Trivariate plots of hand and digit breadths (end points represent means of both trials).

TABLE D-3. Intertrial Differences of Hand and Digit Breadths.

INVESTIGATOR EFFECT

CHARAC-TERISTIC ROOT	PERCENT	Hand Breadth	Digit 1 Breadth	Digit 2 Breadth	Digit 3 Breadth	Digit 4 Breadth	Digit 5 Breadth
		CHARACTERISTIC VECTOR V'EV=1					
0.0876	100.00	0.6519	1.1202	0.7643	1.1215	-0.2813	-0.0480

HOTELLING-LAWLEY TRACE = 0.0876 F(6,111) = 1.62

PROB > F = 0.1480

METHOD EFFECT

CHARAC-TERISTIC ROOT	PERCENT	Hand Breadth	Digit 1 Breadth	Digit 2 Breadth	Digit 3 Breadth	Digit 4 Breadth	Digit 5 Breadth
		CHARACTERISTIC VECTOR V'EV=1					
0.2942	100.00	0.1517	1.5200	-0.0862	1.3657	0.9143	0.2912

HOTELLING-LAWLEY TRACE = 0.2942 F(6,111) = 5.44

PROB > F = 0.0001

INTERACTION EFFECT OF INVESTIGATOR AND METHOD

CHARAC-TERISTIC ROOT	PERCENT	Hand Breadth	Digit 1 Breadth	Digit 2 Breadth	Digit 3 Breadth	Digit 4 Breadth	Digit 5 Breadth
		CHARACTERISTIC VECTOR V'EV=1					
0.0503	100.00	0.1900	-1.4377	0.9232	0.6770	0.1015	0.9709

HOTELLING-LAWLEY TRACE = 0.0503 F(6,111) = 0.93

PROB > F = 0.4755

TABLE D-4. Hand and Digit Lengths.

INVESTIGATOR EFFECT

CHARAC-TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR V'EV=1 Hand Length	Digit 1 Length	Digit 2 Length	Digit 3 Length	Digit 4 Length	Digit 5 Length
0.0138	100.00	-0.0083	-0.1975	0.1279	0.1350	-0.1065	0.0774

HOTELLING-LAWLEY TRACE = 0.0138 F(6,231) = 0.53

PROB > F = 0.7835

METHOD EFFECT

CHARAC-TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR V'EV=1 Hand Length	Digit 1 Length	Digit 2 Length	Digit 3 Length	Digit 4 Length	Digit 5 Length
0.1019	100.00	-0.0725	-0.2011	0.0420	0.1725	0.0056	0.1328

HOTELLING-LAWLEY TRACE = 0.101 F(6,231) = 3.92

PROB > F = 0.0009

INTERACTION EFFECT OF INVESTIGATOR AND METHOD

CHARAC-TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR V'EV=1 Hand Length	Digit 1 Length	Digit 2 Length	Digit 3 Length	Digit 4 Length	Digit 5 Length
0.0382	100.00	-0.0626	0.0350	0.2551	-0.2458	0.1685	0.0272

HOTELLING-LAWLEY TRACE = 0.0382 F(6,231) = 1.47

PROB > F = 0.1886

TABLE D-5. Intertrial Differences of Hand and Digit Lengths.

INVESTIGATOR EFFECT

CHARAC-TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR V'EV=1 Hand Length	Digit 1 Length	Digit 2 Length	Digit 3 Length	Digit 4 Length	Digit 5 Length
0.0632	100.00	0.3003	0.1655	0.0613	0.3686	0.0300	1.3440

HOTELLING-LAWLEY TRACE = 0.0632 F(6,111) = 1.17

PROB > F = 0.3275

METHOD EFFECT

CHARAC-TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR V'EV=1 Hand Length	Digit 1 Length	Digit 2 Length	Digit 3 Length	Digit 4 Length	Digit 5 Length
0.1052	100.00	-0.3838	0.4590	0.1774	-0.5950	0.3919	0.3467

HOTELLING-LAWLEY TRACE = 0.1052 F(6,111) = 1.95

PROB > F = 0.0796

INTERACTION EFFECT OF INVESTIGATOR AND METHOD

CHARAC-TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR V'EV=1 Hand Length	Digit 1 Length	Digit 2 Length	Digit 3 Length	Digit 4 Length	Digit 5 Length
0.0465	100.00	0.4885	0.3705	0.1099	-0.6752	0.8166	0.4863

HOTELLING-LAWLEY TRACE = 0.046 F(6,111) = 0.86

PROB > F = 0.5271

TABLE D-6. Crotch Heights.

INVESTIGATOR EFFECT

CHARAC- TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR V'EV=1 Crotch 1 Height	Crotch 2 Height	Crotch 3 Height	Crotch 4 Height
0.0235	100.00	-0.1430	-0.0486	0.1217	0.0057

HOTELLING-LAWLEY TRACE = 0.0235 F(4,233) = 1.37

PROB > F = 0.2451

METHOD EFFECT

CHARAC- TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR V'EV=1 Crotch 1 Height	Crotch 2 Height	Crotch 3 Height	Crotch 4 Height
0.1027	100.00	-0.0706	-0.1544	0.0220	0.1910

HOTELLING-LAWLEY TRACE = 0.1027 F(4,233) = 5.98

PROB > F = 0.0001

INTERACTION EFFECT OF INVESTIGATOR AND METHOD

CHARAC- TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR V'EV=1 Crotch 1 Height	Crotch 2 Height	Crotch 3 Height	Crotch 4 Height
0.0087	100.00	-0.1568	0.0695	-0.0331	0.0689

HOTELLING-LAWLEY TRACE = 0.0087 F(6,231) = 0.51

PROB > F = 0.7304

TABLE D-7. Intertrial Differences of Crotch Heights.

INTERACTION EFFECT OF INVESTIGATOR AND METHOD

CHARAC-TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR V'EV=1 Digit 1 Crotch	Digit 2 Crotch	Digit 3 Crotch	Digit 4 Crotch
0.1525	100.00	0.2900	0.5549	0.1327	0.5094

HOTELLING-LAWLEY TRACE = 0.1525 $F(4,113) = 4.31$

PROB > F = 0.0028

TABLE D-8. Intertrial Differences of Crotch Heights by Investigators.

INVESTIGATOR 1

CHARAC-TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR Digit 1 Crotch	Digit 2 Crotch	Digit 3 Crotch	V'EV=1 Digit 4 Crotch
0.3233	100.00	0.4414	-0.6315	0.5121	0.4801

HOTELLING-LAWLEY TRACE = 0.3233 F(4,55) = 4.45

PROB > F = 0.0035

INVESTIGATOR 2

CHARAC-TERISTIC ROOT	PERCENT	CHARACTERISTIC VECTOR Digit 1 Crotch	Digit 2 Crotch	Digit 3 Crotch	V'EV=1 Digit 4 Crotch
0.1198	100.00	0.1502	-1.0637	-0.3420	0.7534

HOTELLING-LAWLEY TRACE = 0.1198 F(4,55) = 1.65

PROB > F = 0.1755

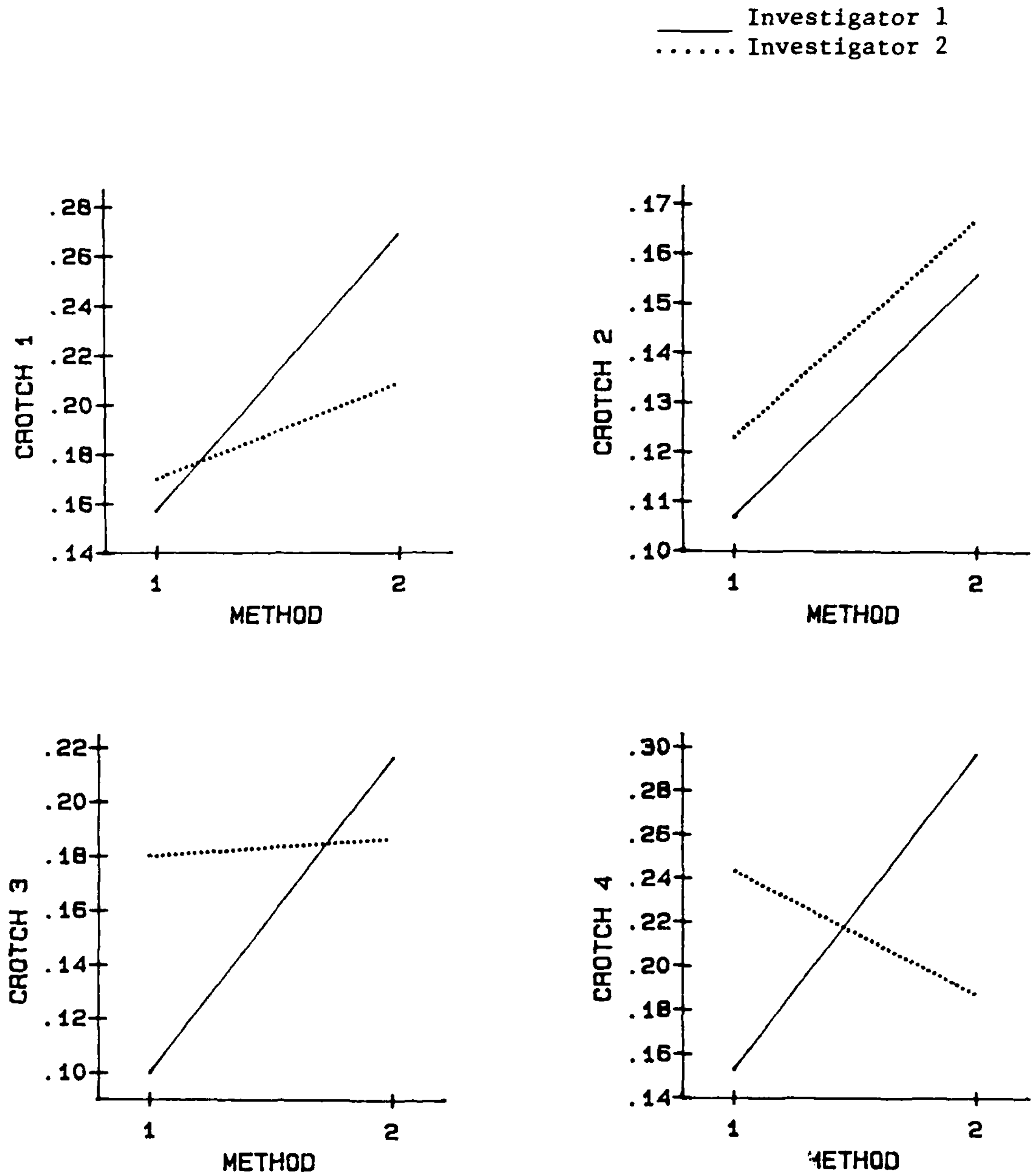

Figure D-2. Trivariate plots of intertrial differences of crotch heights.